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MODERN TURBINE INSTALLATIONS IN WAR VESSELS.

BY DIRECTOR G. BAUER, OF STETTIN.

Translated from the "Annual of the Ship Architects' Association" ("Jahrbuch der Schiffbautechnischen Gesellschaft," for 1909.)

After many years of earnest consideration, recently the way has been quickly paved to the conviction that the steam turbine is preferable in practically all cases to the reciprocating engine as the means of propulsion for naval vessels.

This was shown first in the torpedo boat. The speed of these craft has increased from year to year, so that, with their reduced weight and their enormous power, their safe propulsion with reciprocating engines has become nearly impossible. It is a significant fact that the tending of these engines, which is carried on at times of forced speed in an enveloping cloud of oil, water and steam, has only been made the more difficult by the constantly increasing danger of serious accident at critical moments. Here the turbine was able most easily to win its way, and, moreover, as we shall show later, considering the high speed and power of these boats, the construction of practical turbines met comparatively few difficulties in this field.

After this the installation of turbines in fast cruisers followed quite logically, for in this type of vessel also only such reciprocating engines as were very lightly constructed could be used, while conditions for the building of turbines were very favorable. Just as logical has been the step taken in the introduction of turbines from the small to the large cruiser. Finally, the experience which has been gained in the use of turbines in the types of vessel we have named makes it possible to equip the battleship with this kind of engine with prospects of certain success; now is the opportune moment to replace in this class of vessel also the reciprocating engine by the steam turbine.

The credit for this astonishingly rapid development is due first of all to the inventor of the Parsons turbine, Charles Algernon Parsons, and to the firm which has improved his system. In the short interval of only fifteen years since the building of the first turbine steamer, the *Turbinia,* the Parsons turbine has come to the present state of perfection. Indeed we can say that it has been developed to the point where further essential improvement is scarcely to be expected.

Of course it goes without saying that the success of the Parsons turbine has encouraged constructors to try other turbine systems for propelling ships. Thus in the last few years there have been developed the Curtis turbine and the turbine of the Allgemeine Elektrizitats-Gesellschaft, and later the turbines of Zoelly and of Schichau to be used for marine propulsion.

Following permit me briefly to describe these turbine systems.

The Parsons turbine is a reaction turbine—that is, in this type of turbine pressure is converted into velocity in the ring of fixed blades as well as in that of moving blades. It consists essentially of a drum covered with blades—rings of attached blades or vanes cover it from one end to the other. Figures 1 to 3 show the generally recognized construction. On account of the small fall of pressure or of heat which can be put to use in each ring of blades, the turbine must have a

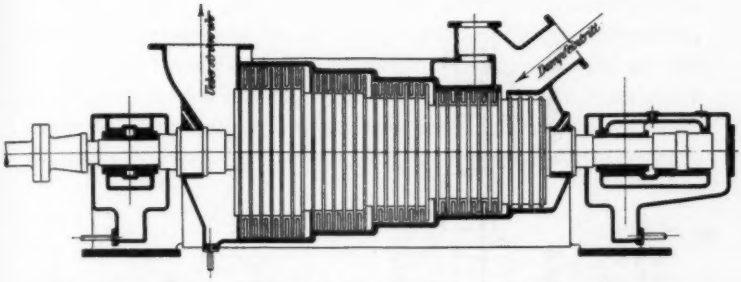


Fig. 1.—Section of H.P. Cylinder, Parsons Marine Turbine.

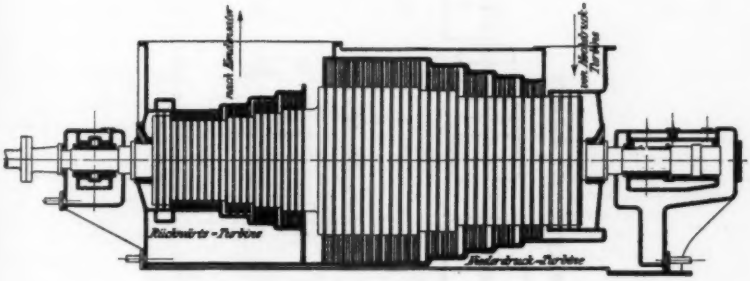


Fig. 2.—Section of L.P. and Astern Turbine, Parsons.

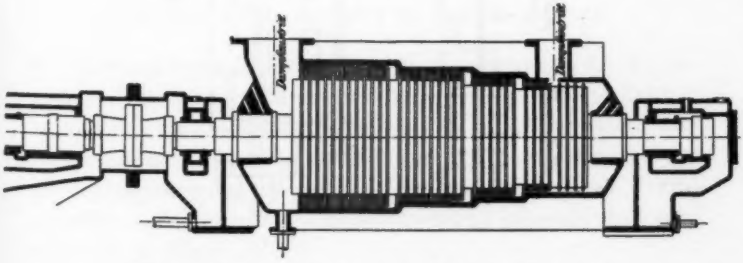


Fig. 3.—Section of Cruising Turbine, Parsons.

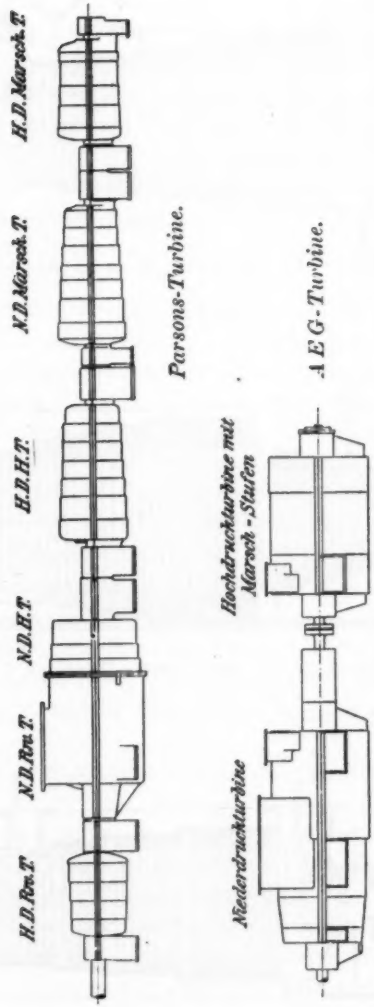


Fig. 4.—Comparison, Parsons with A. E. G. System.

very large number of these rings and therefore is quite long. Figure 4 gives a comparison of the external dimensions of a Parsons turbine and an A. E. G. turbine of the same power, number of revolutions and economy. Contrary to the general arrangement, the Parsons turbine is here drawn as if its entire extension were attached to but one shaft. Under these conditions the Parsons turbine is so long that it would be quite hard

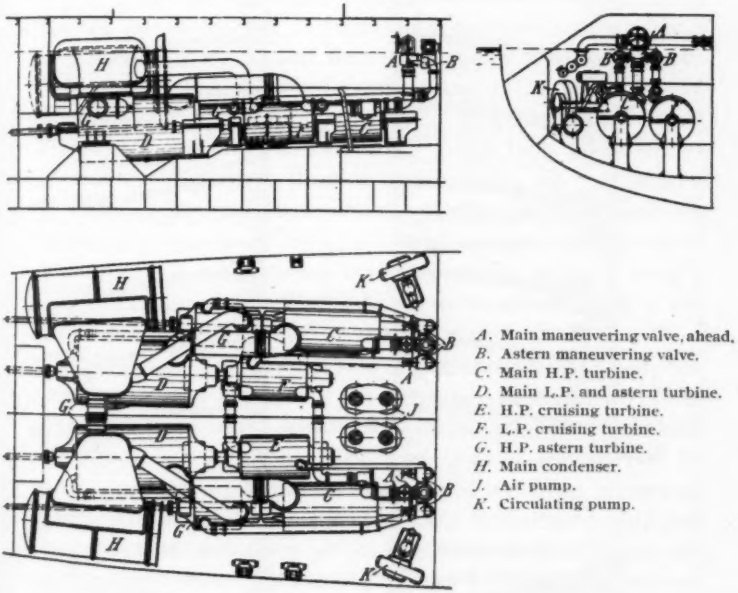

A. Main maneuvering valve, ahead.
B. Astern maneuvering valve.
C. Main H.P. turbine.
D. Main L.P. and astern turbine.
E. H.P. cruising turbine.
F. L.P. cruising turbine.
G. H.P. astern turbine.
H. Main condenser.
J. Air pump.
K. Circulating pump.

Fig. 5.—Cruiser Layout with Parsons Turbine.

to find space enough in the vessel to accommodate it. In applying his turbine to the propulsion of vessels Parsons has got around this difficulty very ingeniously by attaching only a part of the turbine to one shaft and the rest to a second or a third shaft, thus allowing the steam to perform its work on several propeller shafts in turn. The arrangement generally followed is shown in Figure 5.

The Curtis turbine is a pure impulse or pressure turbine, that

is, pressure is converted into velocity only in the set of guiding blades, while in the set of moving blades this velocity is turned into mechanical work. The Curtis turbine consists of bladed wheels on which for the most part the blades are only partially mounted. In the last low-pressure wheels only the steam goes through the whole circumference. The characteristic feature of the Curtis turbine is the exclusive employment of wheels with many rings, that is, of wheels on whose circumference three or four rings of moving blades are arranged, between which are placed two or three rings of reversed blades. This arrangement makes possible relatively an economical employment of very high pressure with a minimum of circumferential speed. This turbine is therefore especially adapted for the generation of a small number of revolutions, provided space is available for its installation, which is difficult to arrange for on account of the large diameter of the wheels. Figure 6 shows the longitudinal section of a Curtis turbine for a small cruiser.

The A. E. G. turbine system is developed from the Curtis turbine. The high-pressure part consists of Curtis wheels, while the principal feature of the low-pressure part is a drum bladed according to the impulse system. The great advantage of this turbine is that the Curtis wheels in the first stages guarantee good use being made of the steam pressure, while but little longitudinal space is taken up, while the drum takes advantage very economically of the great heat energy of the low-pressure part. Figure 7* shows the longitudinal section through the H.P. and L.P. turbines of a small cruiser, both of which, on account of their samll length, can be arranged on one propeller shaft. The thrust bearing is placed between the two turbines. The H.P. part produces no axial thrust. The drum is provided with a solidly built head. The pressure on this head works against the thrust of the propeller, by which it is partly counteracted and partly by the thrust bearing. Compensating pistons and labyrinths are not required. Fig-

*These "photograph" figures, 7-10 inclusive, are not given in the text from which the translation is made.—TRANSLATOR.

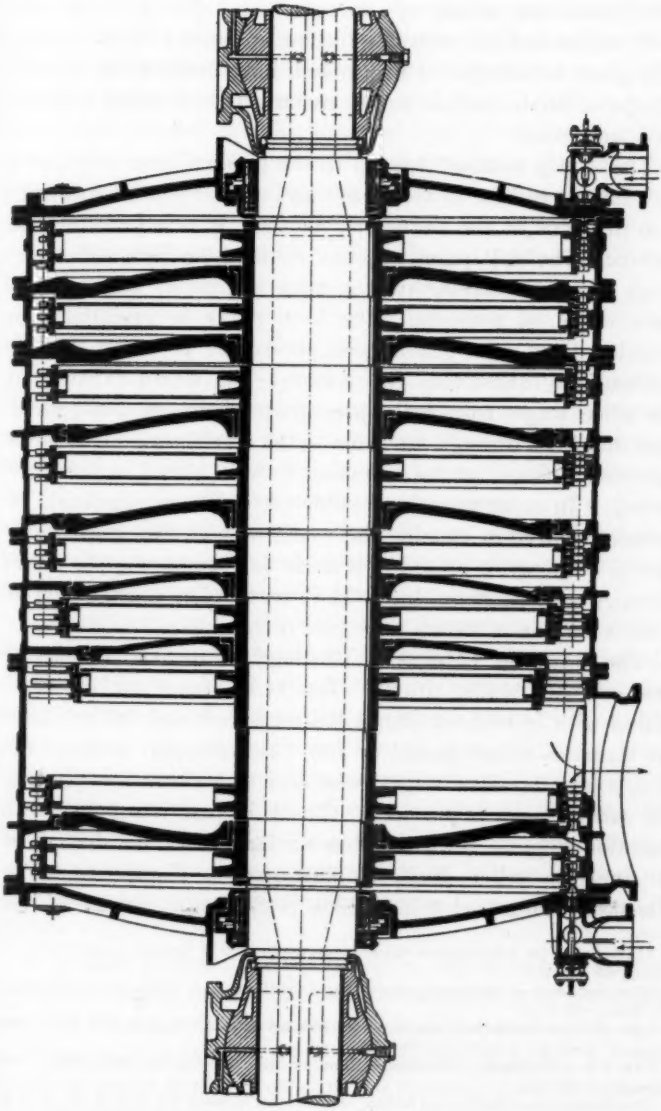


Fig. 6.—Section Through a Curtis Turbine for a Small Cruiser.

ure 8 shows the turbine of a torpedo boat. The H.P. section, L.P. section and the reversing turbine are united in one casing. The great advantages of this system have induced the Vulcan Works at Stettin to take up the manufacture of these turbines on a large scale.

The Zoelly turbine* has up to the present been introduced as a marine turbine in Germany only, on the type of construction in vogue at the Germania Works.† It is a pure impulse turbine. The H.P. part‡ consists of impulse wheels with many rings of blades, having two or more alterations for speed in each range of pressure. The L.P. part§ is essentially an impulse drum with graduations purely for pressure, that is, without any alterations for velocity. The steam expands in the wheel stages from boiler pressure to about one atmosphere, and then goes through the drum to the condenser. This latter pressure suffices for the reversing turbine placed in the same casing. In order to make possible the extensive regulation of power required in running the vessel without any great sacrifice in economy, a provision is made for conducting the steam through various stages in the H.P. part. The construction of such a turbine is shown in Figure 9.

The Schichau (Melms & Pfeninger)‖ turbine consists of one or more bladed drums. The H.P. stages are arranged either with or without alterations for speed, and the provision of blades is either partial or full. Accordingly, between the single high-pressure stages, wherever it is necessary, packing of various types is provided. The L.P. part is supplied with reaction stages. Such a turbine, arranged for the driving of a single propeller shaft, is illustrated in Figure 10. The essential feature of this turbine is the improvement of the

*In Germany the Zoelly turbine has so far only been built of the type constructed at the Germania works.

†Two torpedo-boat destroyers are now being built for U. S. Navy, fitted with Zoelly Turbines.—H. C. D.

‡The H.P. part consists of impulse wheels with several blade rings having two or more changes of velocity in each pressure stage.

§The L.P. part consists of an impulse drum having solely pressure stages without any changes in velocity.

‖For description of this type of turbine, see Nov. 1908 number of J. A. S. N. E.—H. C. D.

balancing apparatus, that is, the device for equalizing the propeller thrust by the thrust of the steam in the turbine, and thereby attaining simplicity and ease of construction. Any propeller thrust not balanced by the axial thrust is taken up by the pressure on the specially-arranged head of the drum. One side of this head is submitted to the steam pressure at a certain place in the system of blading, and the other side to that of the condenser.

We will now proceed to a consideration of the most important points in the preparation of a turbine installation.

The first question which arises in projecting the turbine is: *What power must the turbine have?*

You can get at the solution of this problem in two ways. Either you can ascertain the resistance of the model by means of towing experiments, work out from this by the customary method the resistance of the ship, and then calculate directly on this basis the effective power of the turbine on the shaft; or, you calculate according to the data you have at hand the indicated power of the equivalent reciprocating engine, and figure out in this way the effective power of the turbine.

This latter method appears to be too dependent upon circumstances, but it is to a great extent justified by the fact that all ship yards have a large collection of trial-trip results for the reciprocating-engine vessels that they have turned out, or, in other words, for the large number of ships that have been built, the exact indicated horsepower required for a certain speed is universally known. Since this method gives at the same time a good idea of the characteristics and applicability of the various turbine systems and types of construction as compared with the reciprocating engine, we will carry it further.

It is quite evident that the question, which turbine system and which type of construction of the turbine is to be preferred depends for the most part upon which system and which construction permits the use of the best possible propeller, because when the screw is of the best type for the propulsion of a given ship the amount of effective power required will be the small-

est. Unfortunately, however, the turbine can not be constructed for any desired number of revolutions, but you are forced by its peculiar character not in any instance to go below a certain number of revolutions, or else the requirements of space and weight, on the one hand, and the consumption of steam on the other, will become altogether too great. Under the most favorable conditions for the turbine, that is, on torpedo boats, we have succeeded in being able today to construct the turbine in such a way that the effective shaft power necessary for propulsion by turbine is less than the indicated power of the equivalent reciprocating engines.* In the remaining types of vessels the attainment of this success will be hastened in proportion as the speed of the vessel is increased, and in proportion as the high number of revolutions made necessary by the turbine system is lowered.

As soon, however, as too high a number of revolutions is adopted, the amount of effective horsepower necessary for turbine propulsion rises above the power required in the case of the equivalent reciprocating engine.

A few examples may make this clear.

1. In order to make possible a comparison between the power of a cruiser equipped with Parsons turbines and that of a reciprocating-engine cruiser, and in order to judge from the results attained the relative utility of this turbine system, two entirely equal sister ships were built, one provided with reciprocating engines and the other with Parsons turbines. The ship with reciprocating engines, with exactly the same provision of boilers and the same draught as her sister ship, attained the same maximum speed of about 23.2 knots. At a speed of 23 knots, the shaft power of the turbines, measured with the Fottinger torsion indicator, amounts to 13,800 E.H.P., while, at an equal speed, the cruiser with reciprocating engines gave as her indicated power 11,250 I.H.P. Thus, in order to develop an equal speed, the turbine had to produce

*This statement, from experience in this country, would only apply to the type of turbines where the revolutions per minute are relatively low and approximate to the revolutions used with reciprocating engines. For turbines where the number of revolutions per minute exceed 500 it does not seem to hold true.—H. C. D.

22.7 per cent. more effective horsepower than the indicated power of the reciprocating engine.

2. A few years later the same experiment was repeated with another pair of small cruisers. A comparison of the curves for the shaft power of the cruiser equipped with Parsons turbines and the indicated power of the cruiser with reciprocating engines shows that the turbine cruiser, at an equal speed, had to use considerably more horsepower than the cruiser with reciprocating engines indicated, or in exact figures—

At a speed of 24 knots..... 14.0 per cent.
At a speed of 14 knots..... 7.5 per cent.

3. Corresponding experiments were carried out with two perfectly equal cruisers, of which one was equipped with reciprocating engines and the other with Curtis turbines. When trips were made for purposes of comparison, at a speed of 24 knots the turbine cruiser required 11 per cent. less shaft horsepower than the indicated horsepower of her sister ship provided with reciprocating engines.

4. Similar comparative trial-trip data is at hand for torpedo boats also. A torpedo boat equipped with Curtis turbines of the system of the Allgemeine Elektrizitats-Gesellschaft and a reciprocating-engine torpedo boat of equal dimensions were provided with exactly equal boilers and tried on the same measured mile. With the same forcing of her boilers the turbine reached about 2½ knots more speed. The curve of the shaft power of the turbine boat lies in this case considerably below the curve of the indicated power of the boat with reciprocating engines, so that at the highest speed of the latter the turbine boat required about 4.6 per cent. less shaft horsepower than the indicated horsepower of the boat equipped with reciprocating engines.

Now what is the reason for the various allowances, sometimes positive and sometimes negative, which the designer of a turbine installation must make on the horsepowers attained hitherto with equivalent receiprocating engines?

Table I gives some facts that may throw light on the question.

TABLE I.

POWERS, NUMBER OF REVOLUTIONS AND PROPELLER PROPORTIONS FOR VESSELS EQUIPPED WITH RECIPROCATING ENGINES AND WITH TURBINES.

Vessels compared.	Speeds at which comparisons were made (knots.)	S.H.P.	I.H.P.	S.H.P. more than I.H.P. in per cent. of I.H.P.	Number of revolutions.	Ratio of number of revolutions.	Number of shafts.	Ratio of areas. Propeller (developed) / midship section.
Cruiser with reciprocating engines..	23	...	11,250	...	146	...	2	0.1923
Cruiser with Parsons turbines.	23	13,800	...	+22.7 ...	630	4.32 ...	4	0.0763
Cruiser with reciprocating engines..	24	...	13,600	...	143	...	2	0.2107
Cruiser with Parsons turbines.	24	15,500	...	+14.0 ...	528	3.69 ...	4	0.1404
Cruiser with reciprocating engines..	24	...	14,450	...	187	...	2	.....
Cruiser with Curtis turbines.	24	12,850	...	−11.1 ...	335	1.79 ...	2	.....
Torpedo boat with reciprocating engines.	30	...	10,800	...	323	...	2	0.3784
Torpedo boat with A. E. G. turbines.	30	10,300	...	−4.6 ...	586	1.81 ...	2	0.2879

In the cases in which the additions to be made to the indicated horsepower are positive and very large, either

1. The ratio of the number of revolutions of the turbine to that of the reciprocating engine is especially high, or

2. The ratio of the propeller area to the midship section is especially low, or

3. The number of propellers, and with it the complication

of the stern, is greater than in the case of the reciprocating engine.

These ratios are not figures that you can take about as you wish, but instead will lead you to choose the turbine system of propulsion as the proper one. On account of the large number of stages of the Parsons turbine and its resultant great length, it has to be divided and attached to several shafts. This naturally consumes weight and space, and on this account a very high number of revolutions is chosen for the shaft, a proceeding which is permissible up to a certain degree because of the division of the power on several shafts. (Cf. Table 1.)

Conditions are different with the turbine systems in the case of which the total expansion of the steam takes effect on one shaft. Accordingly, these (the Curtis, Allgemeine Elektrizitats-Gesellschaft, Zoelly, Schichau systems) should all be called single-shaft turbines. In these turbines the large diameter of the partially-bladed wheels in the H.P. part makes possible a low number of revolutions, which in turn permits the employment of large screws. The final result is a proper ratio of the midship section to that of the propeller.

The first employment of the single-shaft system in Germany took place in 1904 in the successful passenger steamer *Kaiser* of the Hamburg-America Line, which was equipped with two A. E. G. turbines placed side by side. These turbines were built in the remarkably short time of seven months, considering the fact that this was a first installation. The first installation of single-shaft turbine propulsion in a torpedo boat was made by the Allgemeine Elektrizitats-Gesellschaft in 1907. In both instances, the determination of the proportions for the propeller, as well as the construction of the vessel, the auxiliary engines, the condensers and boilers, were carried out by the Vulcan Works, Stettin. This firm is also building a cruiser at the present time which is to be equipped with turbines of the A. E. G. system.

Accordingly, in the determination of the power for a turbine installation, the builder should take care to inform himself by means of such compilations as Table I, what relation the

effective power of the turbine has to the power of the equivalent reciprocating engine. Theoretical speculations would hardly lead to any result in this case. However, the results of the numerous installations of turbines which are being made at the present time will soon so supplement existing data that we can proceed quite confidently in our calculation of the necessary power. But it is absolutely necessary that at the trial trip of every vessel equipped with turbines careful measurements of power by means of torsion meters be made. Unfortunately this has often been neglected hitherto.

Now, when the point we have just considered—for what shaft power the installation is to be projected—has been made clear, the builder is next confronted with the question, What number of revolutions shall he choose for his turbine? The choice of the number of revolutions is invariably a compromise in the case of the turbine, because, with this type of engine, from the standpoint of economy, weight and cost, a high number of revolutions is always more advantageous, while the efficiency of the propeller in most cases becomes less as the number of revolutions is raised. Therefore we always carry the number of revolutions of the turbine as high as possible up to the point where the efficiency of the propeller begins to be very poor. This limit may be determined through the examination of the following values:

1. The circumferential velocity of the propeller.
2. The thrust to be counted on for each square centimeter of the developed area of the propeller.
3. The ratio of the pitch to the diameter.
4. The ratio of the developed area of the propeller to its disk area.

These numerical values have limits for the various types of vessels, which may not be exceeded if you would not have a propeller so poor in efficiency that the usefulness of the whole installation would be placed in doubt.

Such limit values are compiled in Table II.

The Vulcan Works, Stettin, in particular, have carried out

thorough investigations for the purpose of ascertaining these numerical values.

TABLE II.

PERMISSIBLE LIMIT VALUES FOR THE CONSTRUCTION OF PROPELLERS FOR WAR VESSELS WITH TURBINE EQUIPMENT.

Ship type.	Circumferential velocity of the points of the blades. Maximum value. Feet per second.	Ratio of pitch to diameter. Minimum value.	Ratio of developed area to disk area. Maximum value.	Thrust pounds, per square inch of developed area, in which $\text{Thrust} = \frac{\text{Effective power} \times 33{,}000}{\text{Revolutions} \times \text{pitch}}$.
Torpedo boats of 30 knots speed and over	215–250	0.95–1.10	0.6 –0.68	19.91
Torpedo boats of 25 to 30 knots speed	180–215	0.92–0.98	0.58–0.65	17.78
Small cruisers of from 22 to 26 knots speed	170–190	0.85–0.95	0.58–0.65	17.78
Large cruisers of from 20 to 24 knots speed	165–175	0.85–0.92	0.58–0.65	14.22
Battleships of from 19 to 22 knots speed	160–175	0.80–0.90	0.58–0.65	13.94

Yet we must first of all describe these ratios as of only approximate value at the present time. It will still be necessary to submit a large number of turbine steamers to thorough-going tests before we can designate exact standards for these points of propeller construction.

The weight of the turbines is closely dependent upon the number of revolutions.

Concerning the weight of a turbine installation various illusions seem to have sprung up of their own accord. It has been assumed that an equipment with turbines would forth-

with be accompanied by a very great saving of weight. To institute a comparison in a few words between the weight of a turbine installation and that of a reciprocating engine is very difficult. Nevertheless it is certain that the greater the speed and the greater the power of the turbine the greater will be the proportionate saving of weight of the turbine as compared with the reciprocating engine. Consequently we are led to expect the greatest saving of weight in very swift vessels with very high power, as in torpedo boats.

Now, for instance, if you assume a speed of 30 knots with a torpedo boat of about 70 meters length and 600 tons displacement, using for propulsion A. E. G.-Curtis turbines you will be able to make a saving in weight of about 13 per cent. over an installation of reciprocating engines. If you drive the same boat at 32 knots speed this saving in weight will amount to 15 per cent., and if you raise the speed to 34 knots the saving of weight will reach about 16 per cent. Here arises a fact that we must consider, and that is, that while the power of the turbine does increase with the speed within the limits mentioned above, this increase in power, contrary to the facts in the case of the reciprocating engine, remains practically without influence upon the weight of the turbines, because it requires simply a lengthening of the blades and only the resultant very slight enlargement of the outer dimensions. Thus, for the increased power, the turbine becomes only a little larger and heavier, while the weight of the reciprocating engine rises somewhat in proportion as the power. Of course the same facts hold practically true with all other types of vessels. It can be said that, in small cruisers of about 25 knots speed, about 7 to 10 per cent. can be saved in weight; while in battleships, which generate proportionally low power and whose speed is comparatively slow, the turbine can not be considered from the point of view of a saving in weight as being much ahead of the reciprocating engine, at least in the present status of naval engineering. In comparing the weights of reciprocating-engine and turbine installations respectively, we should do well to keep in mind that a vessel with the latter

generally gives a higher speed than her sister ship with reciprocating engines, and that we must therefore, in order to obtain a correct comparison of weights, take into calculation, with reference to the weight of the reciprocating-engine installation, its greater power, which corresponds to the speed of the turbine vessel.

Which turbine system will in the course of time earn the right to be called the lightest cannot yet, in the present status of turbine engineering, be predicted.

From the standpoint of the saving in weight there is not much difference between the two most important turbine systems, those of Parsons and of the A. E. G.

Now if power and number of revolutions are determined as we have indicated, then you can form an idea of how much steam will be required by the turbine and of what provision you must make for your boilers. The calculation of the quantity of steam demanded by the turbine for a given number of revolutions and a given power is a matter relating to turbine engineering, and hence passes beyond the bounds of this paper, which deals only with the projection of the turbine installation taken as a whole. It is unnecessary to dwell especially at this point upon the well-known fact that you can count upon the amount of steam necessary for the production of one horsepower decreasing in proportion as the power of the turbine as a whole and the number of revolutions are increased.

With saturated steam, a full load and a good vacuum—at least 92 per cent. measured by a column of mercury—large modern turbine installations require from 5.5 to 6.5 kg. of steam per effective horsepower per hour, in proportion as the relation of number of revolutions and of power is favorable or unfavorable. These figures for steam consumption seem, in fact, to be approximately the same at full load for well-constructed modern turbines of either the Parsons or A. E. G. system mentioned above.

It is a fundamental characteristic of the turbine that at low powers the steam consumption is least favorable. Turbine

constructors have therefore devised various methods for making up this deficiency in the marine turbine. In the case of the Parsons system they try to attain economy at low speeds by adding cruising turbines to the high and low-pressure turbines, so that, at the lowest speed, the steam passes first through a high-pressure cruising turbine, then a low-pressure cruising turbine, then both H.P. turbines and finally through both L.P. turbines. Yet, although you attain with this arrangement comparatively the most favorable steam consumption, the figures are certainly not those which may be cited as ideal in ship propulsion, as we shall see later.

Another plan has been followed in the case of the single-shaft systems. In the A. E. G. turbine, for instance, several wheels are inserted, especially adapted to cruising speed, which, however, in speed under full load may be bridged over by easily-operated by-pass valves. According to the latest improvements the wheels are generally so dimensioned in the first place that they insure economical operation at full load and at cruising speed alike.

Since in the A. E. G. system each separate shaft is driven by its own turbine, and each turbine is also provided with its own condenser and its own set of auxiliary engines, in the case of a three-screw battleship, for instance, at cruising speed you can put simply the two side turbines into operation. The loss occasioned by the drag of the inactive propeller is insignificant. At any rate, in view of the saving in steam which occurs on account of the apportioning of the power to two instead of to three turbines, in operating the boat with just the two side propellers, this loss plays no important rôle. Exact calculations have been made of this loss, so that in this respect you may proceed with perfect clearness, and need not indulge in any form of speculation.

Figures 11 and 23 show the arrangement of such an installation on board a battleship, in which the three turbines employed are of the A. E. G. system.

Beside the advantages we have mentioned, you have less bearing friction, less loss in the stuffing box and less consump-

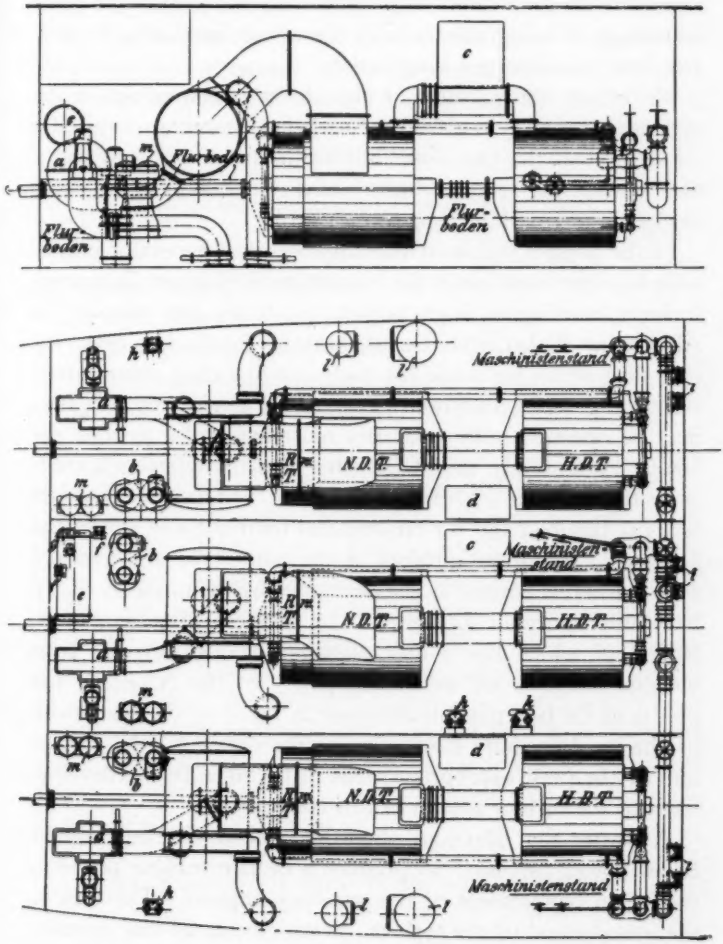


Fig. 11.—Battleship Layout with A. E. G. Turbines.

a. Main circulating pump.
b. Wet-air pump.
c. Hotwell.
d. Hotwell with filter.
e. Auxiliary condenser.
f. Auxiliary air pump.
g. Auxiliary circulating pump.
h. Bilge pump.
i. Oil pump.
l. Evaporator.
m. Dry-air pump.

tion of steam in the auxiliary engines, not to mention the great advantage of being able to keep the whole installation in perfect condition during a long cruise.

Moreover, the question of the steam consumption of the turbine on board is in great need of being cleared up, especially on account of the fact that hitherto the necessary feed water and condensing measurements have generally been made neither in the machine shop or on board.

In the present status of investigation it is generally impossible to experiment upon the consumption of steam in marine turbines running at high power, and until the present the Allgemeine Elektrizitats-Gesellschaft of Berlin has been the only firm which has made for itself any first-class contrivances for testing steam turbines. The testing devices of this firm may be operated with quantities of steam up to 50 tons per hour. Accordingly the Allgemeine Elektrizitats-Gesellschaft is in the position of being able to test turbines for torpedo boats at full load and for cruisers and battleships at almost the full load. To brake turbines of the latter type and measure such enormous powers as are developed by them, the A. E. G. has built hydraulic brakes of the greatest dimensions, the largest of which has a disk diameter of 3.5 meters. It is obvious that this self-sacrificing policy of the A. E. G. has produced the best possible influence in favor of the attainment of the most accurate knowledge of the details of the turbine and of the most appropriate steps to be taken in the development of the turbine system of this company.

A matter that plays an important rôle in determining the boiler power necessary to produce a certain turbine power is the steam requirement of the auxiliary engines. Previous to the introduction of the turbine, measurements of this quantity were made only to a slight extent. Lately the necessity has first become apparent for obtaining perfectly clear ideas as to the amount of steam needed for this purpose. The steam requirement of the auxiliary engines amounts to about 10 to 18 per cent. of that required to produce the motive power of the propeller turbines, depending upon how much the draft is

used. It begins to reach its highest value from the moment when the forced-draft blowers are put into full operation. Thorough measurements of the steam requirement for auxiliary engines in torpedo boats have given about the following figures:

TABLE III.

STEAM REQUIREMENT FOR THE AUXILIARY ENGINES, IN PER CENT. OF THE STEAM REQUIREMENT OF THE MAIN ENGINE.

	With reciprocating engines.	With turbines.
At highest forcing of the draft,	15	17
80% of power of main engine,	12	16
60% of power of main engine,	10	15
40% of power of main engine,	10	15
20% of power of main engine,	12	16

These figures are according to extensive experiments which were carried out by the Vulcan Works, Stettin.

The figures are higher for turbine boats on account of the independent wet and dry air pumps and the oil pumps and the better steam consumption of the turbine itself.

The amount of coal to be burned in the boilers is indicated by boiler evaporation figures which show how many kilograms of water can be converted into steam per each kilogram of coal burned. By the use of superheaters, with which practically all war vessels are at the present time provided, with the best small-tubed tubulous boilers, undoubtedly to be preferred to the large-tubed type, you can count on the following evaporation.

TABLE IV.

EVAPORATION FOR SMALL-TUBED TUBULOUS BOILERS.

	Water vaporized, per pound of coal.
Torpedo boats, under highest forcing of draft,	7.5–7.8 lbs.
Torpedo boats, under moderate forcing of draft,	7.8–8.2 lbs.
Cruisers and battleships, under highest forcing of draft, ...	8.0–8.5 lbs.
Cruisers and battleships, under moderate forcing of draft, ...	8.8–9.5 lbs.

With the question of the requirement of steam is very closely associated that of the influence which the vacuum in the condenser exerts upon the power of the turbine. While in the case of the reciprocating engine you may satisfy yourself with a very low vacuum, in the steam turbine a very high vacuum has become necessary. In very economically-constructed reciprocating engines for war vessels the expansion of the steam is at the highest a twelve-fold one, while the increase in the volume of the steam in a modern ship turbine may amount to as much as 150 to 200 fold. This possibility of expansion of the steam results from the fact that in the turbine the steam is not limited by the fixed size of the receptacle in which it must expand, but its increase in volume rests principally upon the dimensions of the cross-section through which the steam flows in the last part of the turbine. The influence of a good vacuum upon the power of the turbine is accordingly a very important one, as is shown in Table V.

In consequence of these facts particular attention has been bestowed upon the construction of condensing apparatus on board turbine vessels. It may almost be said that marine steam engineering began from the very time when turbines were first introduced to work out methods by which it might be possible to make a radical improvement of the vacuum obtainable on board. Consequently, modern turbines work at the present time with a vacuum of about 92 per cent. measured with a column of mercury, at forced speed, and up to 94 per cent. at the speed maintained in steaming trials. The attempt to construct as perfect condensing apparatus on board as possible has led to the invention of sensible air-pump systems, and in consequence the steam turbine has been put to use in these pumps also. Figure 12 shows the projected mechanical equipment of a battleship, according to which the air and circulation pumps customary with reciprocating-engine propulsion are replaced by turbo-pumps of the A. E. G. system. The simple arrangement of these pumps and the small amount of space they require make a very favorable impression, and there

is no doubt that in the course of time this pumping system will be put into actual operation.*

TABLE V.

EXAMPLE OF THE INFLUENCE OF THE VACUUM UPON THE CONSUMPTION OF STEAM IN TURBINES.

A. E. G. Marine Turbines.

Vacuum in per cent.	About 76 per cent. of the normal amount of steam.			About 31 per cent. of the normal amount of steam.		
	Pounds of steam per S.H.P. per hour.	Increase (+) or decrease (—) in pounds of steam per S.H.P. at 90 per cent. vacuum.	Increase or decrease in pounds of steam per S.H.P. at 90 pr. ct. vacuum per 1 pr. ct. change in vacuum.	Pounds of steam per S.H.P. per hour.	Increase (+) or decrease (—) in pounds of steam per S.H.P. at 90 per cent. vacuum.	Increase or decrease in pounds of steam per S.H.P. at 90 pr. ct. vacuum for 1 pr. ct. change in vacuum.
	Pounds.	*Per cent.*	*Per cent.*	*Pounds.*	*Per cent.*	*Per cent.*
95	12.35	—8.94	—1.79	14.84	—14.81	—2.96
92	13.09	—3.41	—1.71	16.42	—5.70	—2.85
90	13.56	.....	±1.68	17.42	.....	±2.76
88	14.00	+3.25	+1.63	18.34	+5.32	+2.66
85	14.64	+7.97	+1.59	19.69	+13.04	+2.61
80	15.65	+15.45	+1.55	21.80	+25.19	+2.52
75	16.64	+22.76	+1.52	23.68	+35.95	+2.40
70	17.61	+29.92	+1.50	25.53	+46.55	+2.33

In discussing the question of the steam consumption of turbines it is necessary to consider the influence also of the superheating of the steam. Two methods of superheating

* This, from present experience in this country, is more or less doubtful. The best results for marine condensing apparatus seem to be given by the use of a good single-acting wet-air pump and the use of an augmentor of the Parsons type. For circulating pumps the small steam engine still promises to remain for some time as the most economical and reliable motor for this particular service.—H. C. D.

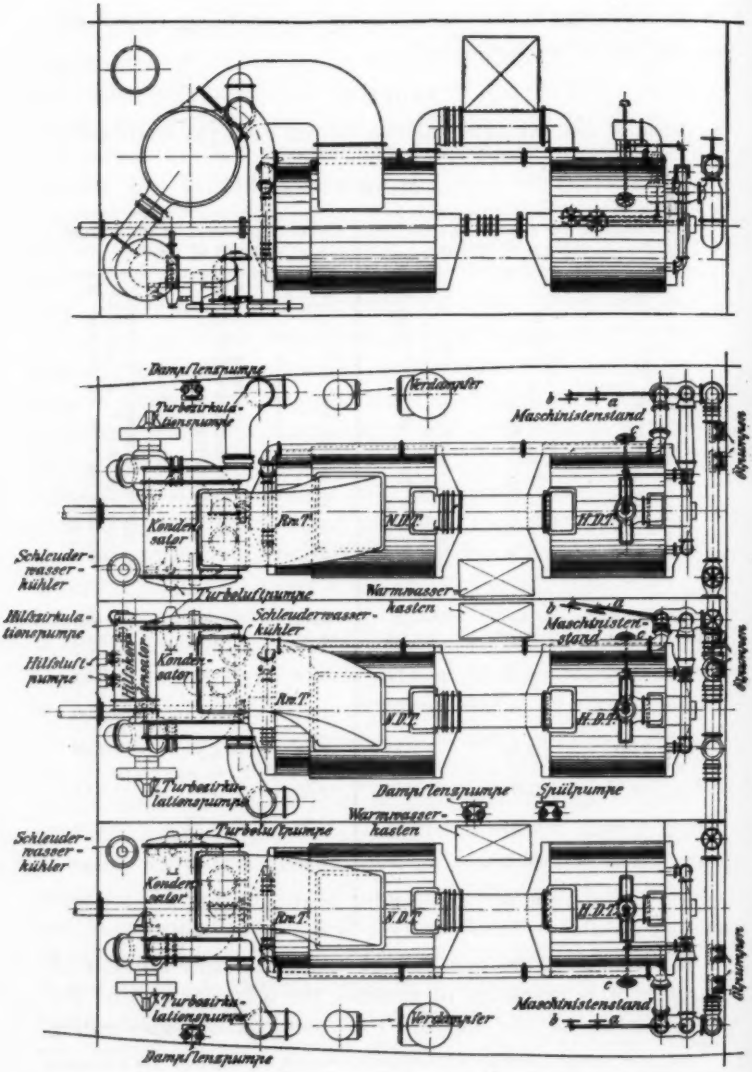


Fig. 12.—Turbine Layout for Battleship with Turbo Air Pumps and Turbo Circulating Pumps.

come to mind for use on board ship as well as for stationary engines, either the directly-fired superheater, in which the steam is brought to a temperature higher than normal by the burning of coal on a separate grate, or the so-called indirectly-fired superheater, in which the steam is allowed to circulate through a system of pipes that are heated by the gases from the main furnace fires. The latter method is not practicable on board war vessels, on grounds of space and also because of the necessary saving of weight. Moreover, such superheaters require great heating surface, because the temperature of the gases differs too little from that of the steam to be superheated.* Thus, on board war vessels we are restricted to the directly-fired superheater. And yet, on torpedo boats the employment of even this type of superheater is absolutely precluded, because all the room that can be given to boilers must be put to the best use possible for the production alone of the necessary steam; so that there then remains room for the directly-fired superheater only in cruisers and battleships. The form which has been given to such superheaters by Wilhelm Schmidt of Cassel, one which may, according to all indications, be described as particularly applicable to use on board ship, is shown in Figure 13. As may be seen from the drawing, a few water tubes are inserted in the superheater, which terminate above in one water chamber and below in two, and are intended to keep the superheating tubes proper from coming into contact with the injurious jets of flame. Nevertheless this superheater must be described as one with direct firing, since the production of steam in the protective water tubes is only a secondary consideration. However, if this

*This opinion, with regard to superheaters, may perhaps apply to the type of boiler used in the German Navy, but certainly does not apply with regard to the boiler used in the United States and British Navies. It is difficult to see how the separately-fired superheater on naval vessels is to have any advantage in space over the indirectly-fired one when the latter is properly arranged. The superheaters on the boilers as fitted in the United States and British Navies require no additional space or attendance, and the additional weight is almost negligible. The indirectly-fired superheater in these installations is placed where the temperature of gases is from 1,000 degrees to 1,800 degrees Fahrenheit, or almost the same temperature that would be safe with the directly-fired superheater. Moreover, the indirectly-fired superheater is automatic in its operation, requiring no extra attendance whatever. On the other hand, the separately-fired superheater requires special attending personnel, and, no doubt, special care to secure the proper operation.—H. C. D.

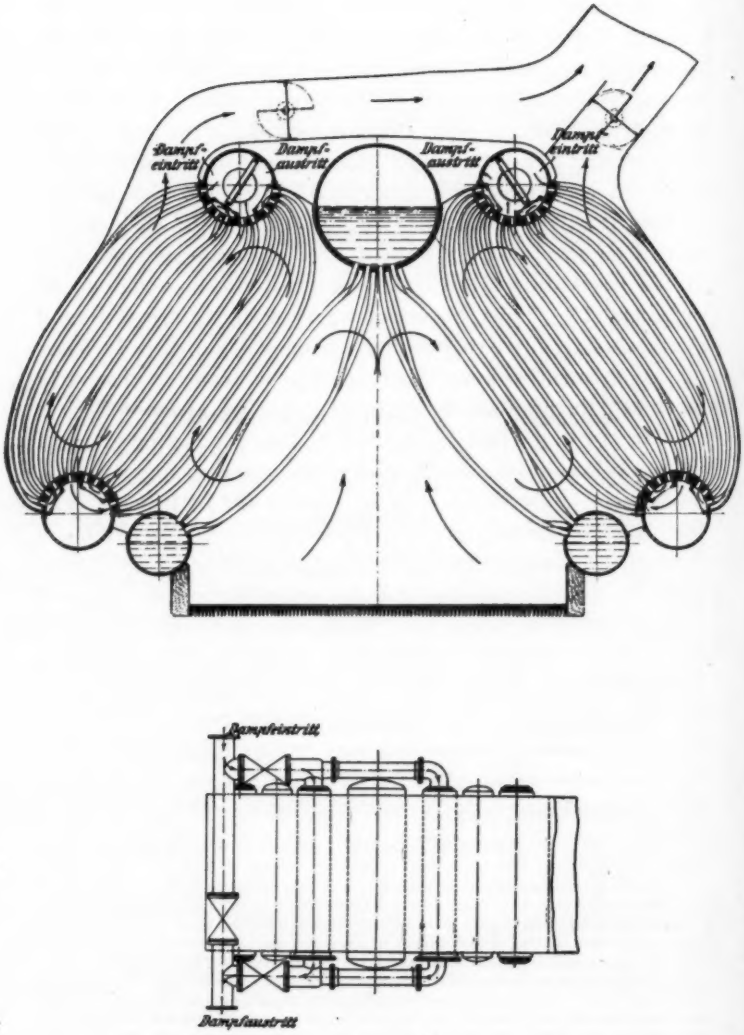


Fig. 13.—CENTRAL SUPERHEATER. SCHMIDT SYSTEM.

heater should prove unsatisfactory in one way or another, it could be easily turned into a regular boiler by inserting a bundle of water tubes to run between the upper and lower water chambers. On board war vessels at forced speed such a superheater would be able only to dry the steam, but at cruising speed a superheating of the steam of about 100 degrees Centigrade would be effected, that is, from a temperature of about 200 degrees Centigrade to 300 degrees Centigrade.*

TABLE VI.

EXAMPLES OF THE INFLUENCE OF SUPERHEATING UPON THE CONSUMPTION OF STEAM IN TURBINES.

A. E. G. Turbine Installation.

Superheating.	About 39 per cent. of the normal amount of steam.				About 21 per cent. of the normal amount of steam.			
	Pounds of steam used per S.H.P. per hour.	Decrease in amount of steam used per S.H.P. with dry steam.	Decrease per 50 deg. F. superheating in amount of steam used per S.H.P. with dry steam.	Amount of superheating necessary to improve the steam consumption 1 per cent.	Pounds of steam used per S.H.P. per hour.	Decrease in amount of steam used per S.H.P. with dry steam.	Decrease per 50 deg. F. superheating in amount of steam used per S.H.P. with dry steam.	Amount of superheating necessary to improve the steam consumption 1 per cent.
°F	*Lbs.*	*Per cent.*	*Per cent.*	°F.	*Lbs.*	*Per cent.*	*Per cent.*	°F.
0	15.90	...	...	...	22.07	...	...	...
68	15.06	5.27	2.61	38.82	20.11	8.89	4.45	36.05
104	14.37	9.57	2.39	39.52	18.91	14.29	3.57	37.04
140	13.82	13.04	2.17	40.30	19.31	18.48	3.08	37.85
176	13.36	15.95	1.99	41.05	17.22	21.98	2.75	38.55
212	13.03	18.03	1.80	42.01	16.60	24.78	2.48	39.25
248	12.76	19.70	1.64	42.98	16.09	27.07	2.26	39.96

*It is doubtful whether a temperature as high as this could be regularly used without difficulties in piping, valves, cylinders of auxiliaries, etc.—H. C. D.

The saving in steam which is brought about in the turbine by drying and superheating is quite considerable. Table VI shows how much saving of steam this superheating produces under various conditions.

However, the fact must not be overlooked in this connection that the superheating of the steam causes to a certain degree extra consumption of coal. Accordingly, in order to form an adequate conception of the clear gain in coal effected by the use of superheating apparatus, you must first reckon what saving in coal is brought about by the saving in steam caused by the use of superheated steam in the turbine, and then subtract from that the amount of coal which the superheater itself consumes. Table VII shows a compilation of such data.

TABLE VII.

EXAMPLES OF THE CALCULATION OF AMOUNT OF COAL SAVED BY THE EMPLOYMENT OF A SUPERHEATER ON BOARD A CRUISER.

Saturated steam.	*Superheated steam.*
Condition in the turbine: pressure, abs. =250 lbs. moisture...4 p. c.	Condition in turbine: pressure, absolute=250 lbs. $t = 572°$ F. corresponding to 212° superheating.
Power of turbine.....7,900 S.H.P.	Power of turbine.....7,900 S.H.P.
Steam consumption per S.H.P. per hour.....15.65 lbs.	Steam consumption per S.H.P. per hour.....12.35 lbs.
	Decrease in amount of steam consumed compared with consumption of saturated steam.....21.1 per ct.
Heat taken up per lb. of steam, with feed water at 176° F.....2,271 B.T.U.	Heat taken up per lb. of steam, with feed water at 176° F.....1,163 B.T.U.
Heat expended per S.H.P. per hour.....16,123 B.T.U.	Heat expended per S.H.P. per hour.....14,385 B.T.U.
Total amount of steam for the turbines, per hour, 7,900×15.66...123,714 lbs.	Total amount of steam for the turbines per hour, 7,900 × 12.36..... 97,565 lbs.

Saturated steam.	*Superheated steam.*
Factor of evaporation (Verdampfungsziffer), 8.7	Factor of evaporation.....8.7
	Coal consumed for generation of steam $= \frac{97,565}{8.7}$ per hour.....11,215 lbs.
	Thermal value of coal per pound.....12,600 B.T.U.
	Coal consumed for superheating in a directly-fired superheater of 62 degrees efficiency per hour.....1,689 lbs.
Coal consumed per hour: $\frac{123,714}{8.7}$.....14,220 lbs.	Total amount of coal used per hour.....12,899 lbs.
Coal consumed per S.H.P. per hour for the turbines alone, without the auxiliary engines.....1.799 lbs.	Coal consumed per S.H.P. per hour for the turbines alone, without the auxiliary engines.....1.633 lbs.
	Saving in coal in consequence of superheating of steam.....9.24 per ct.

It is apparent that, for instance, in this project for a cruiser, in a swift endurance trip at 80 per cent. of the maximum speed the total saving in coal brought about through the use of a superheater amounted to only 9.24 per cent., while the saving in the quantity of steam supplied to the turbine was 21.1 per cent. under the same conditions. The balance of the coal was lost through the firing of the superheater. In this problem the efficiency of the superheater acts as a very significant factor. Now taking the data of Figure 7 we should find that with an improvement in the efficiency of the superheater, as a natural consequence the figure for the saving in coal would immediately become more favorable; for it would rise to 11.31 per cent. with the efficiency of the superheater at 75 per cent. Even though the final gain brought about through superheating the steam does not seem to amount to much just now, it will

still be necessary to keep the whole matter continually before our eyes, and, before we make any final judgment upon the value of superheating, wait for the results of the extremely interesting investigations which are being carried on in various places at the present moment. Yet we may predict that superheating will prove to be more suitable for turbine systems in which the high-pressure part is only partially bladed than for the Parsons turbine. In the case of the latter, superheating is to a certain extent dangerous on account of the small clearance of the blades in the high-pressure part, unless, indeed, the clearance is made so large that the expansion of casings, wheels and blades, unavoidable with superheating, will be kept from becoming a source of danger. However, this would, on the other hand, lessen the working efficiency of these turbines. Accordingly, the possibility of employing superheating must be considered as a further advantage of the single-shaft turbine.

We will now leave the question of the consumption of steam in the turbine and take up another subject that is of very great importance in estimating the value of a given turbine installation. This is the problem of providing for sufficient *backing power* and *maneuvering capacity*. The first ship-turbine installations were extremely deficient from the point of view of backing power. The giving up of weight and space to a special backing turbine naturally appeared inconvenient, and constructors at first attempted to carry out this troublesome addition to the turbine installation with as little sacrifice of weight and space as possible. However, it was soon recognized that too much economy should not be attempted in this direction, particularly in war vessels, so that today engineers regard it a working rule that in large war ships a power should be given to the backing turbine of from 40 to 45 per cent. of that of the go-ahead turbines. Since the number of revolutions with a backing power of 40 to 45 per cent. is considerably smaller than the number of revolutions with full speed ahead, the fact must not be overlooked that this backing power produces a moment of rotation of 60 to 65 per cent. of that gen-

erated in full speed ahead. Now in making a rule for properly proportioning the backing power to the power of the go-ahead turbine you must bear in mind the condition that this must be brought about without allowing the steam pressure in the boilers to suffer any great reduction, or, in other words, that this backing power must be produced with an amount of steam which the boilers are easily able to make. With the faulty backing turbines of the first Parsons turbine ships it came about that at the command "Full speed astern" the steam pressure in the boilers went down several atmospheres. Now when many commands followed in alternation, partly for backing, partly for going ahead, in the end the steam pressure in the boilers became so low that the auxiliary engines began to cease operating, and it became necessary immediately to close down quite strongly on the backing throttle valve and be satisfied with a much lower backing power, or else have the whole installation of engines come to a complete standstill. If the requirement mentioned above, of providing for 45 per cent. of the power for going ahead with the same quantity of steam as for forced speed ahead is given proper attention, it will be possible entirely to avoid such difficulties as have arisen, for instance, in the single-shaft turbines in connection with nozzles for the high-pressure part. With such turbines we are easily able to proportion the entrance diameter of the nozzles with such exactness that with a certain boiler power only a certain amount of steam can pass through. Often in the construction of these vessels the specification is laid down that it shall be possible to bring the ship to a standstill in a certain length of time, from one to two minutes (the latter figure in the case of large and heavy ships) or, as otherwise stated, that the ship shall not run more than so many meters after the moment when the command "Stop" is given. Now we can work out what power the backing turbine must have in order to fulfill the above conditions in the following manner:

According to a fundamental principle of mechanics the diminution of the active force of a ship is equal to the work

of the resisting force. The active force of the ship at the beginning and at the end of the stopping experiment is known. At the beginning it is equal to half the mass of the ship multiplied by the square of the speed from which it is to be brought to a stop, while at the end of the stopping experiment it is equal to zero. Likewise, with a given backing turbine the other side of the equation is known. Now the resisting force is composed of two elements: the resistance which the water offers to the progress of the ship, decreasing during the stopping experiment from a maximum resistance corresponding to the speed at the beginning down to zero at the end, and the backing thrust of the propeller which operates during the whole course of the experiment. This backing thrust is somewhat greater than would correspond to a normal backing power. This arises from the fact that during the first moments when the steam rushes into the turbine a far greater moment of rotation is produced than answers, as a general rule, to the backing power exerted. The stopping time and distance worked out by means of this equation correspond very well indeed with the results that have been derived from actual experiment. Careful comparison between such reckoned and measured values were made for the first time by the Vulcan Works, Stettin.

It may be stated that the most modern turbine war vessels in the construction of which the requirements which would have to be fulfilled by the backing turbine were known from the very outset, have turned out to be just as easy to maneuver as the ships equipped with reciprocating engines. Indeed, in the case of a torpedo boat provided with A. E. G. turbines which has had her trial trip very recently, the length of time in which she could stop was even less than that of her sister ship furnished with reciprocating engines. From the point of view of a quick changing of the motion of the vessel from ahead to astern, the following points are in favor of the turbine:

1. You have no reversing apparatus to fuss with, but

reverse the ship simply by closing the ahead and opening the astern maneuvering valves.

2. Contrary to the case of the reciprocating engines, you can venture at any time to change from full power ahead to full power astern, without having to bring the machinery to a stop in between.

3. It very often happens in the case of the reciprocating engine that you have to experiment several times with the reversing lever before you actually succeed in reversing the engine. This is entirely done away with in the case of the turbine; you are sure every time of producing the desired reversing immediately. This shows an advantage in the turbine which should be very highly estimated in war vessels, because of the fact that in time of war it is not always possible to have so well-trained engineers as are necessary to handle many-cylindered reciprocating engines surely and readily.*

Now if the propeller is as large as possible, of course the turbines are so much the more easy to maneuver, since screws of large area, on account of their very size, exert the more influence upon the reduction of speed of the vessel from the moment when they are stopped. Further, the large Curtis wheels are especially well suited for use in powerful backing turbines, because with these a very strong moment of rotation is produced. These are advantages of the single-shaft systems with which, on account of the small number of revolutions, larger propellers can be made use of than in the case of Parsons turbine installations, and in which the backing turbine can be provided with large wheels.

Now that we have dealt with the power for propulsion ahead and astern, the number of revolutions, and the steam to be generated for the turbines, we come to the subject of the arrangement of the turbines in the vessel.

Let us first consider turbine installations in torpedo boats.

* These three stated reasons rather overdraw the case for the turbine. The cases mentioned under 3, where any difficulty is met with in reversing a reciprocating engine, are so exceptional that they may as well be neglected. When all is said and done the fact remains that the reciprocating engine has decided advantages over the turbine in handling and maneuvering.—H. C. D.

Figure 14 shows the Parsons turbine installation of a torpedo boat with three shafts and a transverse bulkhead. The latter serves the purpose of rendering the boat still able to move

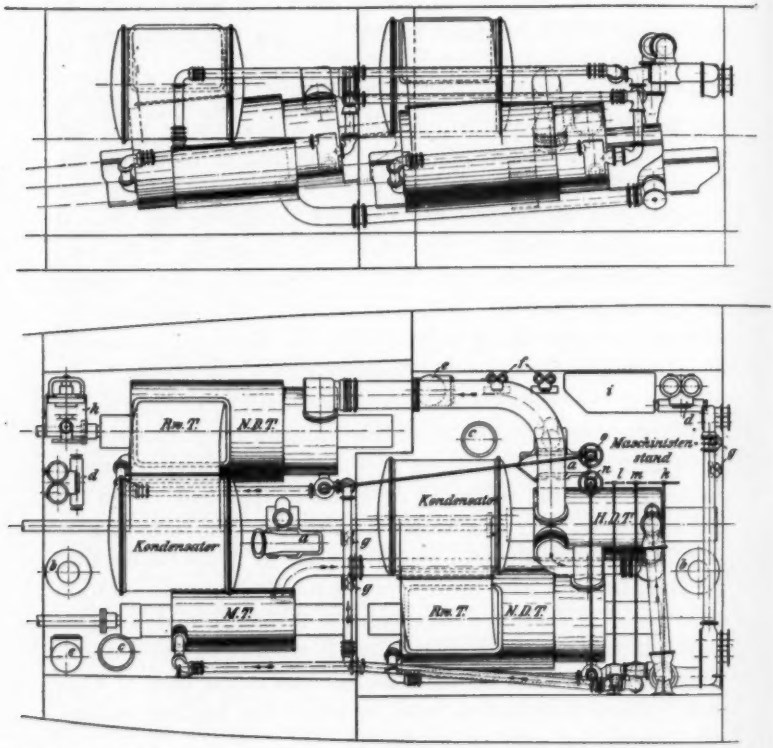


Fig. 14.—MACHINERY LAYOUT WITH PARSONS TURBINE FOR A TORPEDO BOAT.

a. Circulating pump.
b. Wet-air pump.
c. Dry-air pump.
d. Main-feed pump.
e. Evaporator.
g. Oil pump.
h. Dynamo.
i. Hotwell.
k. Throttle, full speed ahead.
l. Throttle, cruising.
m. Throttle to maneuvering valves.
n. Maneuvering valve, forward engine room.
o. Maneuvering valve, after engine room.

when one compartment has become unusable. At a slow speed the steam first passes through a cruising turbine on the starboard shaft, then the H.P. turbine on the central shaft,

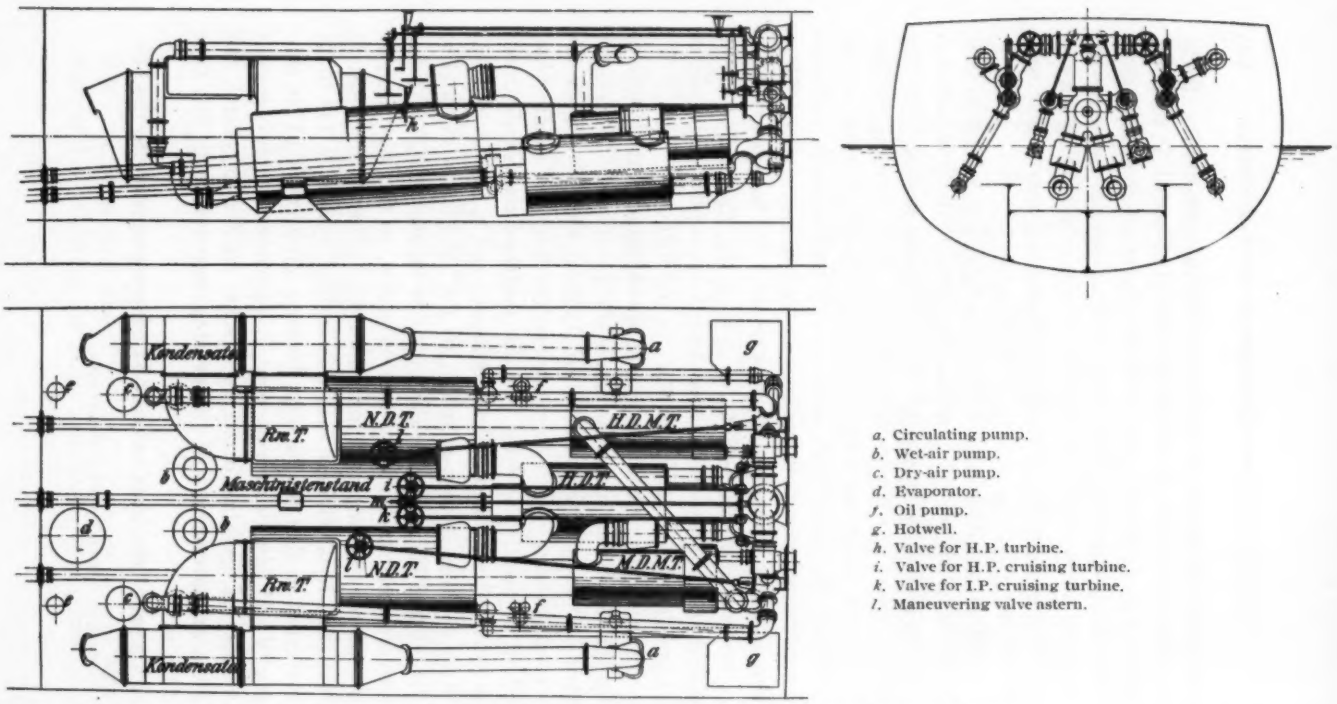
and finally the two L.P. turbines on the two side shafts. Backing turbines are placed within the casings of both L.P. turbines. Since at an ordinary speed all three shafts are interdependent, each low-pressure turbine must have a special maneuvering valve by means of which rotation of either side shaft may be reversed as desired. This is a complication unavoidable with this system.

Another installation of Parsons turbines for a torpedo boat is shown in Figure 15. In this arrangement there is neither a longitudinal nor a transverse bulkhead. At a slow speed the steam passes in succession through the H.P. cruising turbine on the port shaft, the medium-pressure cruising turbine on the starboard shaft, the H.P. turbine on the central shaft, and then directly to the two L.P. turbines on the two side shafts. Here also especial maneuvering devices have to be employed, in order that you may be able to reverse the rotation of either side shaft as you wish. These devices are controlled by means of two hand wheels on the starting platform.

The arrangements in the engine room become far simpler in torpedo boats provided with single-shaft turbines. Figure 16* shows a projected installation of A. E. G.-Curtis turbines for a torpedo boat. Each compartment contains just one turbine, which is intended to drive just one shaft. Each compartment is provided with a complete condenser and a full set of auxiliary engines, so that each half of the installation is equal to the other. Each turbine has only one maneuvering valve for motion ahead and one for motion astern, so that any kind of motion may be imparted immediately to either turbine just as desired. It is obvious that this turbine system is far to be preferred to that of Parsons, because, on account of its simplicity and ease of arrangement, it guarantees a much greater security of operation and a far quicker answer to control, and these are advantages of the greatest importance in this type of boat.

Torpedo-boat installations of turbines according to the Ger-

* This figure is not in the text.—TRANSLATOR.



a. Circulating pump.
b. Wet-air pump.
c. Dry-air pump.
d. Evaporator.
f. Oil pump.
g. Hotwell.
h. Valve for H.P. turbine.
i. Valve for H.P. cruising turbine.
k. Valve for I.P. cruising turbine.
l. Maneuvering valve astern.

Fig. 15.—Machinery Layout, Parsons Turbine, for Torpedo Boat.

mania-Zoelly system, cf. Figure 17, and the Schichau system, cf. Figure 18, are quite similar to the one described above, with A. E. G.-Curtis turbines. With regard to their applicability for use in ships both of these installations have the aforesaid advantages of single-shaft systems.

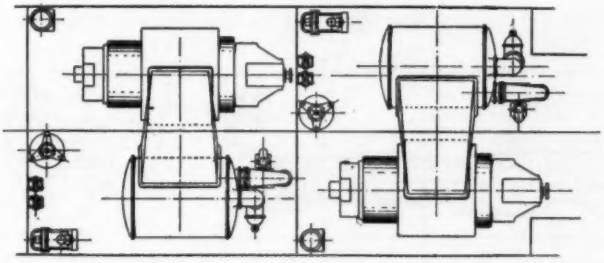


Fig. 17.—Turbine Layout for a Torpedo Boat With Zoelly Turbines.

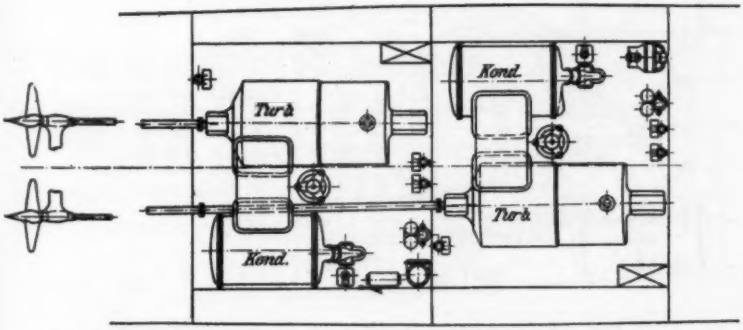


Fig. 18.—Machinery Layout for a Torpedo Boat with Schichau (Melms & Pfeninger) Turbines.

Now we will pass to the question of turbine installations for cruisers. Figure 19 shows a Parsons turbine installation for a cruiser with four shafts. At economical cruising speed the steam passes first through the H.P. cruising turbine on the starboard inner shaft, then the L.P. cruising turbine on the port inner shaft, from here to the two H.P. turbines on the two outer shafts, then to the L.P. turbines on the two inner shafts,

and finally out to the two condensers. At the present time the defects of this complicated arrangement have been recognized, and it has been decided to omit the cruising turbines. A disadvantage of the arrangement we have described above is that before changing from full to cruising speed there must be a mutual agreement between the two compartments concerning the putting into operation of the cruising turbines, and

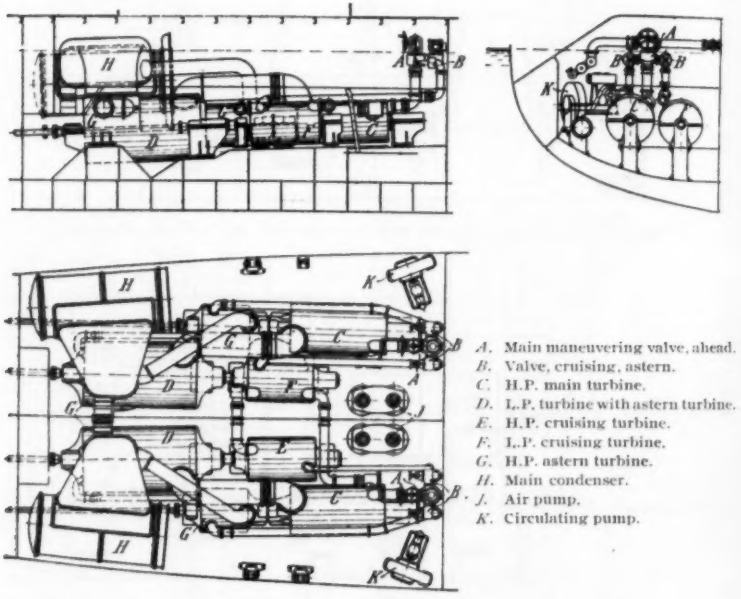

A. Main maneuvering valve, ahead.
B. Valve, cruising, astern.
C. H.P. main turbine.
D. L.P. turbine with astern turbine.
E. H.P. cruising turbine.
F. L.P. cruising turbine.
G. H.P. astern turbine.
H. Main condenser.
J. Air pump.
K. Circulating pump.

Fig. 19.—CRUISER LAYOUT WITH PARSONS TURBINES.

this, of course, hinders the rapid execution of orders. For instance, as a general rule, at cruising speed, one screw cannot be set going astern with full power and the other ahead with full power without a change in command; the order for cruising speed must first be countermanded before the other can be put into effect.

Figure 20 shows an A. E. G. turbine installation for a cruiser. The arrangement is manifestly simpler than the one

we have just described, for there are only two shafts, each of which is driven by a complete turbine, including the backing rotor. Port and starboard sides are separated by a longitudinal bulkhead. Each compartment has its own condensing

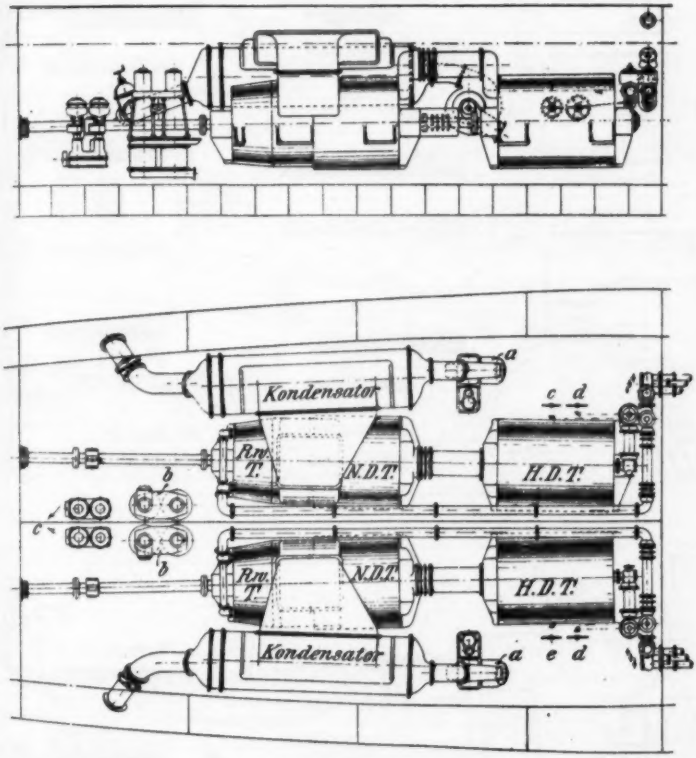


Fig. 20.—MACHINERY LAYOUT FOR A CRUISER WITH A. E. G. TURBINES.

a. Circulating pump.
b. Wet-air pump.
c. Dry-air pump.
d. Maneuvering valve, ahead.
e. Maneuvering valve, astern.

apparatus and set of auxiliary engines, and is therefore entirely independent of the other. For maneuvering one maneuvering valve for propulsion ahead suffices for each turbine. Maneuvering is thus simpler even than in the case of the

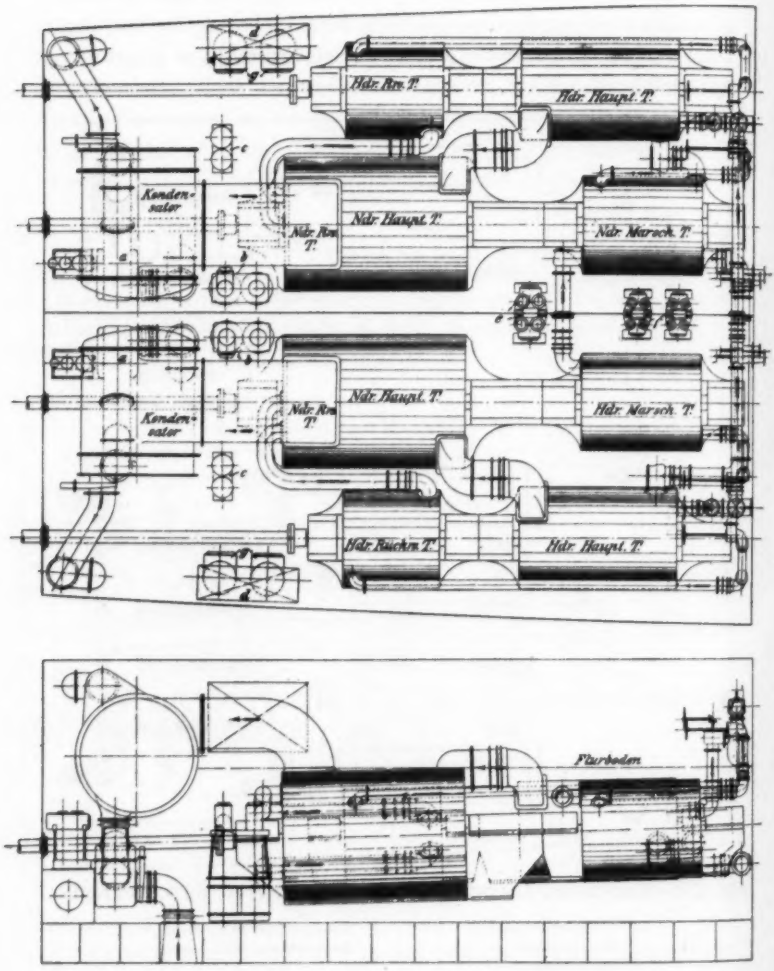


Fig. 21.—MACHINERY LAYOUT, PARSONS' TURBINE, FOR A BATTLESHIP.

a. Circulating pump.
b. Wet-air pump.
c. Dry-air pump.
d. Hotwell.
e. Bilge pump.
f. Oil pump.
g. Evaporators.

reciprocating engine. This installation excels in certainty of operation and in ease of arrangement on account of the independence of each compartment from the other, and as a natural consequence maneuvering is much simpler than in the case of the Parsons turbine, because of the fact that no mutual understanding between the two compartments, separated by a longitudinal bulkhead, is necessary when a change in speed or direction is to be carried out.

In the case of a battleship the Parsons turbine is arranged with four shafts in much the same way as in the cruiser installation described above. A battleship arrangement is shown in Figures 21 and 22. In this case, also, at an economical

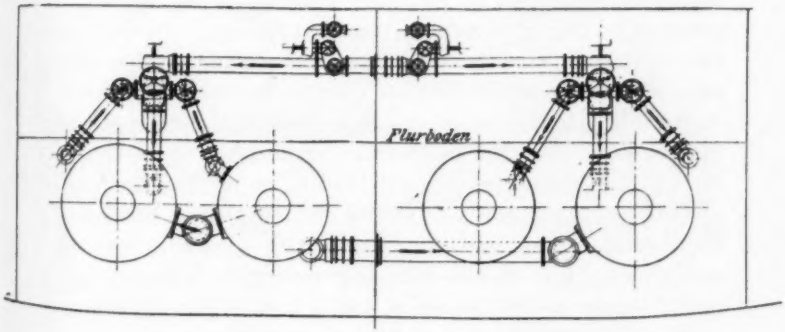


Fig. 22.

speed the steam first passes through a H.P. cruising turbine, then a L.P. cruising turbine, then the two H.P. main turbines, and finally the two L.P. main turbines. A H.P. backing turbine is attached to each outer shaft and a L.P. backing turbine to each of the two central shafts. Two compartments are formed by a central longitudinal bulkhead, which are perfectly independent of each other in the management of their turbines only at full speed. On account of the disposal of turbines described above, even at slow speeds, all four shafts, both condensers and both sets of auxiliary engines must be kept going. Hence no overhauling of the machinery of any nature can be made even at a time when it is most necessary. The arrange-

ment of an installation of turbines of the A. E. G. system in a battleship is quite different from the one we have just described, as may be seen in Figure 23. The engine-room space is divided into three sections, each of which is provided with a complete main turbine with its backing turbine. Each turbine drives one shaft. All three sets of turbines are completely independent; each compartment has its own condensing apparatus and provision of auxiliary engines. The installation is therefore identical with a similar one with three reciprocating engines, since all the eminent advantages of the three-screw system hold here with full force. Here are three separate, but perfectly equivalent, maneuvering units, and hence the machinist in charge of each can concentrate his undivided attention on the set of turbines placed in his care. He receives his commands directly from the commanding bridge, and even at cruising speed does not have to consider his relation to the engineers in the other compartments, because none of the screws is dependent in operation upon either of the others. As we have already mentioned, cruising speed may be developed by using the two side screws only, so that at this speed the central turbine and all its accessory apparatus may be overhauled. For maneuvering and turning the vessel in narrow channels the middle screw, which is especially adapted to such movements, comes in very handy. In case of accident or of injury in battle, instead of two complete aggregates you have three that you can use. With this arrangement the engine-room floor plates and controlling platform are quite low down, just as in the case of reciprocating engines. Thus the engineers are saved the discomfort of the hot air rising from the machinery. This is a great advantage over the Parsons turbine installation. In the latter the floor space is always so taken up that the starting platform must be placed over the turbine. However, this part of the engine room is the hottest on account of the continual rising of the heated air.

Another form of turbine arrangement for a battleship with three screws is shown in Figure 12. In this the air and circulation pumps are driven by turbines of the A. E. G. system.

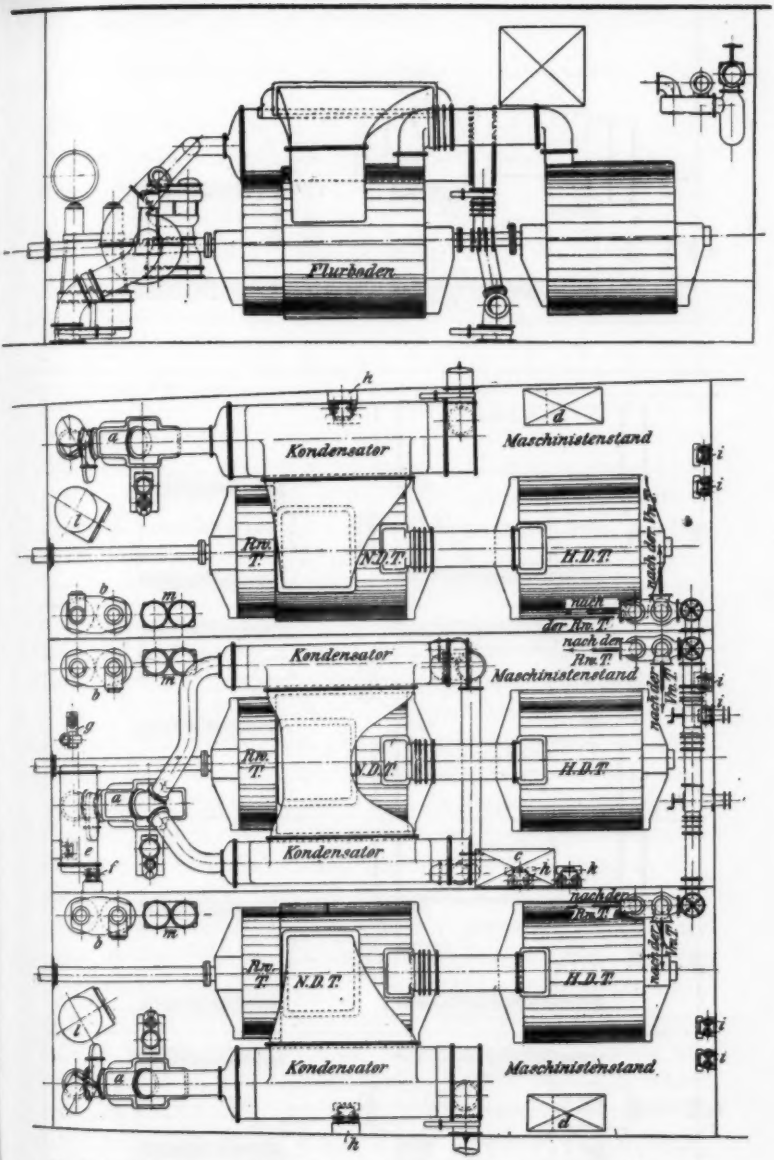


Fig. 23.—Machinery Layout, A. E. G. Turbine, for a Battleship.

a. Circulating pump.
b. Wet-air pump.
c. Hotwell.
d. Hotwell with filter for auxiliary condenser.
e. Auxiliary condenser.
f. Auxiliary air pump.
g. Auxiliary circulating pump.
h. Bilge pump.
i. Oil pump.
k. Sanitary pump.
l. Evaporators.
m. Dry-air pump.

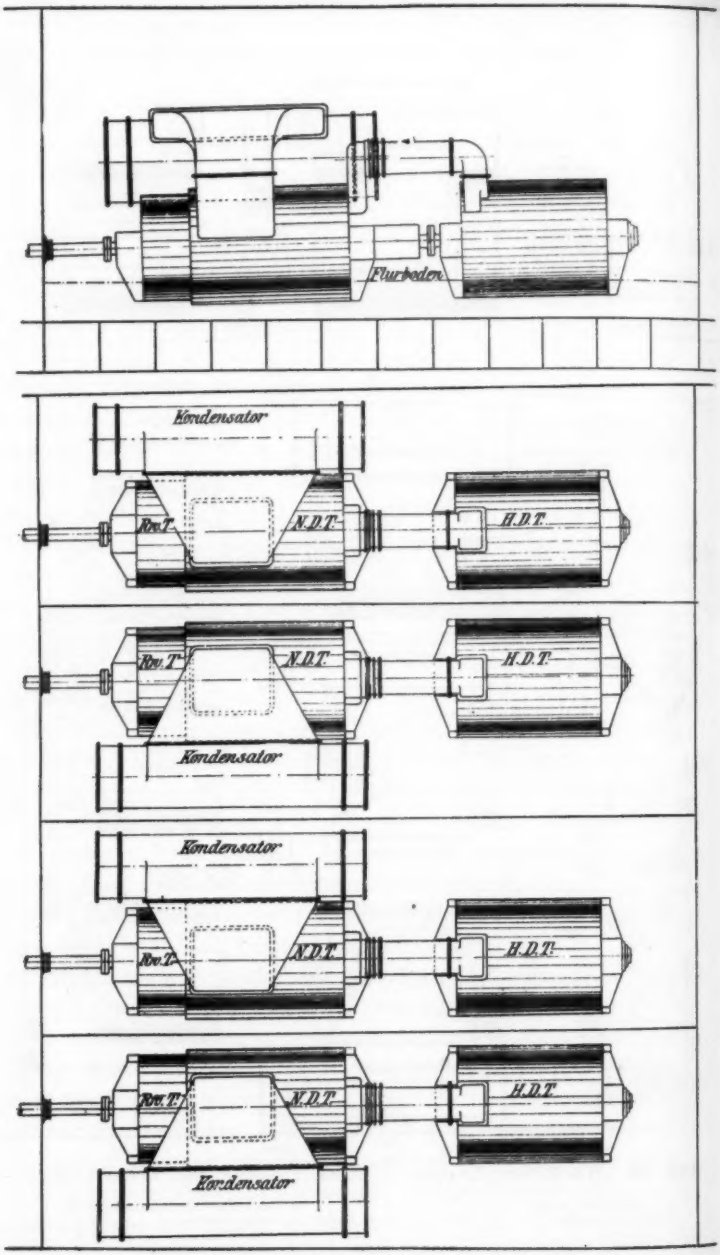


Fig. 24.—Turbine Layout for Battleship, A. E. G. System, 4 Shafts.

This innovation is to be commended on account of its small requirement of space, its light weight and the fact that it makes possible a very high vacuum.

Of course, turbines of the A. E. G. system may also be used for the propulsion of a battleship with four shafts. Figure 24 shows such an arrangement. However, the fact must not be overlooked in this connection, that we should here lose the eminent advantages of the three-screw system.

The construction of the stern is, of course, much more complicated in the arrangement with four lines of shafting necessary in battleships and cruisers with turbine installations according to the Parsons system than it is when the single-shaft systems are made use of, in the case of which no more shafts have to be employed than in reciprocating-engine vessels. The stern is weakened by many lines of shafting, and there is more danger of vibration. At the same time the influence upon the ship's resistance is unfavorable. Experiments have been made in which solely through the provision of a tube leading from the stern bearing to the propeller strut—causing apparently only a very slight modification of the conditions of the flow of water at the stern of the vessel—an increase of speed of 0.38 knot was attained. Figure 25* shows the customary arrangement, and the same after the insertion of the tube. Conducting many shafts through the stern also prevents to a considerable extent use being made of the space lying in that part of the vessel. Figure 26 shows a comparison of the sterns of two small cruisers, equipped one with Parsons turbines and the other with Curtis.

Vibration occurs in turbine vessels principally at the stern of the vessel, obviously on account of the action of the screws. This is an advantage over the vessels with reciprocating engines, in which poorly balanced engines have caused, under certain circumstances, such vibrations extending through the whole hull of the vessel as to make the aiming of guns difficult, and, through the disturbance of the compass, to cause the ship to be steered out of its course.

* Figs. 25 and 26 are not reproduced.

Which system of turbines is the best from the point of view of lessening the vibration cannot be stated with certainty at the present time. However, the lesser number of revolutions of the single-shaft turbines would seem to be of advantage in this regard. Since the single-shaft turbines use large propellers, and since with large ships in which this system is installed the propeller blades can be adjusted and in this way the pitch and the number of revolutions be changed, it becomes possible for the number of revolutions which are unfavorable from the point of view of causing a vibration of the stern to be avoided.

In consideration of the points of simplicity and of reliability of operation, the single-shaft systems are undoubtedly to be preferred to the Parsons turbine. The number of stuffing boxes is much less in the case of the former. For instance, in a cruiser with turbines of the A. E. G. system there are only eight, while in the Parsons turbine cruiser shown in Figure 19 there are as many as sixteen. Therefore the provision of stuffing boxes is much more complicated in the case of the Parsons turbine, and the number of valves connected with the stuffing boxes is larger. The same holds true with the pillow and thrust blocks. In a small cruiser with A. E. G. turbines there are eight pillow blocks and two thrust blocks, while in a small cruiser with Parsons turbines sixteen pillow blocks and six thrust blocks are necessary.

The greater part of the accidents which have happened heretofore in turbine steamers are blade accidents, which have been brought about by the striking together of the blades. These accidents are decidedly nasty, because of the fact that the turbine must be stopped immediately if you would avoid having every bit of the blading destroyed. Such mishaps have come about frequently with Parsons turbines. This danger is absent in the case of single-shaft turbines, because in the H.P. part they have only wheels with heavy blading and ample clearances, while the drums which form the essential feature of the L.P. part may be given full clearances without fear of any waste. Table VIII shows the differences in clearance of the various

stages in turbines of the two systems we have been comparing, in twin cruisers and torpedo boats.

TABLE VIII.

RADIAL CLEARANCE OF BLADES, IN INCHES.

Turbine.	Cruiser, Parsons turbines.	Cruiser, A. E. G. turbines.	Torpedo boat, Parsons turbines.	Torpedo boat, A. E. G. turbines.
High-pressure cruising..	.043-.051	.098-.118	.039-.047	.079-.118
Low-pressure cruising...	.047-.059			
High-pressure main.....	.055-.067	.098-.138	.047-.063	.079-.118
Low-pressure main.....	.079-.118	.098-.138	.071-.098	.079-.118
High-pressure backing..	.063-.079	.098-.157	.063-.087	.118-.138
Low-pressure backing...	.079-.110			

The blading itself is in general stronger in the single-shaft systems than in the Parsons. Moreover, the Parsons turbine has a far greater number of moving and guiding rings, and thus many more blades than the single-shaft turbines. For example, in two cruiser turbines of equal power, the Parsons turbine has 650,000, and the A. E. G. 370,000 blades, and in two equivalent torpedo-boat turbines the Parsons system has 250,000 and the A. E. G. 148,000 blades.

The strength of the blading is of considerable importance from the point of view of security of operation. In lowering the turbines into their casings after an examination it is easy to bend or twist a very weak blade by letting it come into contact with other other blades or some part of the casing, and this alone is sufficient to cause an accident later on. Of course the danger of such injury to the blades in raising or lowering them is much less when they are strong than when they are weak. It cannot be said that the question of raising and lowering is of especial difficulty in any turbine system. Special lifting apparatus is necessary, with which it is possible first to raise the upper part of the casing and then the rotor.

After we have gained a few more years' experience in the construction of turbines, accidents of the sort we have mentioned will become very rare, and examination and overhauling will take place only periodically, probably while the vessel is laid up for the winter. There is no doubt but that the cost of repair of the turbine will be eventually far smaller than that of the reciprocating engine.

Permit a few words at this point on combination installations of reciprocating engines and turbines.

Many projects have been worked out aiming to replace the less economical part of the turbine, the H.P. section, by a reciprocating engine, the exhaust steam from which shall later be used in the turbines. With turbine engineering at its present high state of development, we may confidently state that the idea that this combination would be practical in war vessels is a thing that has had its day. For only consider that through the employment of two entirely separate propulsive motors in one and the same vessel, the mechanical equipment is greatly complicated and the work of the engine-room personnel made far more difficult. These faults have settled the fate of the combination installation.

It is impossible to put a steam turbine and a reciprocating engine into operation on one and the same shaft, since the high number of revolutions which the turbine requires would bring about quite unreasonable demands on the reciprocating engine, and *vice versa*. It is therefore necessary to conduct the steam, after it has done its work in the reciprocating engine, to the turbines placed on other shafts; and in this way you make the various shafts dependent upon each other, and produce a condition which is disadvantageous in ship propulsion, considered from every point of view. Moreover, the noiselessness and cleanliness that are such permanent characteristics of turbine vessels would be overbalanced by the extra noise and spray produced by the reciprocating engine running at the high speed made necessary by its combination with turbines. Further, under these circumstances it is necessary to provide space consuming and inconvenient steam shunting and change valve

apparatus, which are needed in order to make the shafts independent of each other in maneuvering and in case of accident. In short, we must conclude that such combination installations have the faults instead of the advantages of each of the systems united.*

Now, if we gather up the results of the foregoing observations we shall see that modern turbine construction for war vessels must tend more and more toward the employment of the single-shaft systems, since these are best fitted for use on

* The objections here cited appear to be more academical than practical. The reciprocating engine can not with advantage be placed on the same shaft with the turbine, but the combination arrangement can be effected on either three or four shafts, and each shaft arranged so that it can work independently whenever this disposition may be required.

The combination system is not to be urged for any kind of swift torpedo vessel or for a twenty-five-knot liner where full speed is the normal speed. But the combination is urged for vessels of medium speeds and for vessels where the ordinary service speed is well below full power. The following important reasons for favoring the combination system present themselves:

1. The advantage of superior maneuvering power. The lack of maneuvering power of the turbine does not lay so much in the question of levers and valves as it does in dynamic steam torque and propellers. The small turbine propellers, to use a common expression, do not get a hold on the water like the large-diameter propellers of the reciprocating engine. Hence turbine vessels with their small screws are considerably harder to maneuver than are vessels equipped with reciprocating engines. In battleships maneuvering abilities are of paramount importance. By adopting the combination system the maneuvering qualities of the reciprocating engines are retained.

2. The combination is also urged on the ground of securing reasonable economy at the cruising speed. The performance of the combination is fully fifty per cent. better at low cruising speeds than is that of the turbine with or without cruising turbines. The advantage of economy on the part of the combination can also be maintained right up to full speed conditions.

The combination will require slightly less weight, for a battleship, than the turbine installation, either Parsons or Curtis system. The combination will also require considerably less space than the Parsons system and no more than is needed for the Curtis. The combination presents less complication than the Parsons and no more than the Curtis, whichlatter demands a size and weight of casing and rotor that presents some objectionable difficulties for handling and installing. When such high powers as 30,000 horsepower are put in a vessel (unless the revolutions are low and the diameter of the propellers can be large) it is desirable (in order to secure desirable propeller conditions) to divide the power on more than two shafts.

With the combination system the beneficial effect of superheating can be fully realized. With turbines this is in some measure doubtful and is not used with the Parsons system. If composition material is used for blading it is unlikely that any extensive degree of superheating can be used without detrimental effect upon the durability of the blades.

A long-stroke reciprocating engine, well balanced and fitted with forced lubrication, does not have either the noise or spray mentioned to any very objectionable extent, and can be operated in as cleanly a manner as are the turbines. A turbine engine room in hot weather is still somewhat removed from being that delight and joy forever that some of the turbine enthusiasts would have us believe.

For the performance required of a battleship's machinery and for large moderate-speed merchantmen the combination arrangement gives both the advantages of the turbine and those of the reciprocating engine and this combination of advantages can be secured with less weight and less space.—H. C. D.

board war ships when we take all points into consideration. This is no new contention; this conviction is everywhere gaining an increasingly greater following.

In addition to the home country of the Curtis turbine, the United States, where a cruiser with Curtis turbines has given the best results, and where turbine installations for two battleships* as well as for two torpedo boats are now in process of construction, the Navy of Germany is also energetically taking up the trial of single-shaft turbine systems, and is, indeed, building torpedo boats and cruisers equipped with turbines of this type. Even in England, the conservative home of the Parsons turbine, it has already begun to be thought that the single-shaft systems deserve the closest attention. At the John Brown Works in Glasgow a 2,500-horsepower turbine is under construction, which is intended to demonstrate the advantages of this system to the English Admiralty. This turbine is to be built under the oversight of Chief Engineer Pigott, of the International Curtis Marine Turbine Co. All of this indicates that, as a final result of the thorough investigation that is being made on both sides of this controversy, in the course of time a simple system on the basis of the single-shaft idea will be evolved which will be even more stereotyped than the reciprocating engine is today.

The following discussion of this paper was made by

DIRECTOR BOVERI, OF BADEN, SWITZERLAND.

Your Royal Highness: Gentlemen: I have noticed with pleasure that at the beginning of his paper Mr. Bauer expressed the view that steam turbines can now be regarded as undoubtedly the correct propulsive machines for war vessels. In this his conclusions are the same as the ones that I had the honor of presenting you at this place two years ago. Since Mr. Bauer has based his views exclusively on the results attained with Parsons turbine vessels—for such turbines are the only ones which have up to the present received practical application in this field—I am necessarily led to the conclusion that the

* Only one battleship and three destroyers thus far.—H. C. D.

various dogmatic remarks that he made in the course of his essay against the Parsons turbine were not meant to be taken very seriously. (Laughter.) Hence I will refrain at this moment from taking up by way of refutation the various points that he made. That would take up too much of your time. Nevertheless, I must make this much of a reservation—my company will probably take the opportunity later, in a special publication, of dealing with this very subject.

Today I wish to deal only with the fundamental proposition made by Mr. Bauer, and that is that the turbine which is to be especially looked upon as the turbine of the future for ships and for war vessels is the single-shaft turbine, and, further, that we may consider that we have already at the present time reached this solution of the problem. It may, indeed, be correct, speaking academically solely, that a single-shaft installation, or, in other words, one in which the whole force of the steam pressure is exerted upon a single shaft, is to be preferred to an installation in which two or more interdependent shafts are provided. However, this view can only be judged correct in so far as it is substantiated by results from practical applications of the various turbine systems. There we come into a very different point of view, and the conclusions reached may not quite tally with those attained as the result of academical discussion.

In regard to the causes that lead us to make a division of the installation upon several shafts, Mr. Bauer has worked out his argument from incorrect premises. In Figure 4 of his essay he has indulged in a little joke by making a caricature of a Parsons turbine (laughter) of astonishing length, although he must know quite well that for various considerations of efficiency, etc., we do not arrange a turbine on one shaft in this way, and that his picture therefore gives quite a wrong impression. Taking this picture as a basis, he has proceeded to infer that a division of the turbine on several shafts is necessary, because the turbine is too long to be arranged on one shaft, and because by making a division the long sections of the turbine can be placed beside each other. This view is incor-

rect. The reason why we divide the turbine upon separate shafts lies in the better efficiency, in the better mechanical effect that we are able to attain in this way. As a matter of fact, Mr. Bauer in his essay has given us premises that lead directly to the conclusion that the mechanical efficiency is better in the divided turbine. He has told us that the efficiency of a turbine rises in proportion with the power and number of revolutions. Now in making a division upon several shafts, in part both of these advantages are attained and in part only one. A few simple examples may make this plain to you.

A torpedo boat with single-shaft turbines has two turbines which are independent of each other, and which, if I assume for example a power of 12,000 H.P. for the whole installation, each produce 6,000 horsepower. Thus, the boat has two engines of 6,000 H.P. each. Now if this installation were so arranged, according to the Parsons idea, that I had a high-pressure turbine on a central shaft, the steam from which expanded into low-pressure turbines on the two side shafts, then in effect I should have a single 12,000-H.P. engine; for at these powers the improvement of the efficiency lies in the high-pressure part alone, and the division of the low-pressure part of the turbine into two sections no longer has an unfavorable influence upon the final efficiency of the whole installation, but, on the contrary, in combination with the high-pressure part causes a marked improvement. Now we have before us a contrast between the efficiency of a turbine of 6,000 H.P. and that of a turbine of 12,000 H.P. According to the statements of Mr. Bauer the turbine with 12,000 H.P. is, of course, the better. But this is not all; he has shown us that the higher number of revolutions is the better. Now if I provide a boat with two shafts then I have a number of revolutions of the propeller of, let us say, about 600 per minute. But if I provide the boat with three shafts and three propellers I shall obtain about 800 revolutions per minute. Therefore, I have in one case a turbine in the boat of 12,000 H.P. and 800 revolutions, and in the other case two turbines of 6,000 H.P. and 600 revolutions each.

In cruisers we have somewhat different conditions to deal with, since in both the two-shaft arrangement of the single-shaft turbines and the four-shaft arrangement of the Parsons turbines—for, up to date, this has been the method of arrangement employed with the Parsons system in this class of vessel—we have had, at least at the highest power, two separate mechanical units to deal with. Thus even in the Parsons turbines under consideration the installation has not been a mechanical unit. But under these conditions the difference in the number of revolutions comes even more favorably to light, because the vessels have four shafts each instead of two, and thus four propellers instead of two; and an installation with four propellers can sustain a correspondingly higher number of revolutions.

However, we have the further advantage to consider, that the cruising turbines provided are arranged in series in such a way that at the lower powers we have, generally speaking, a unit installation in these cruisers. Therefore we have the two united advantages of great power and of a high number of revolutions.

These facts are still more striking when we compare a three-shafted battleship installation of single-shaft turbines and a four-shafted battleship installation of Parsons turbines. Here we have on the one hand the increasing of the number of propellers from three to four, and on the other hand a division into only two-unit machines instead of three. Here also we have, at slow speeds, a consumption in a single-unit engine of the whole quantity of steam used. Accordingly the efficiency of this arrangement must be by far the better one.

That its efficiency would be the better one is shown by the statements of Mr. Bauer. He has pointed out in quite positive terms that the Parsons turbines have furnished abundant evidence of the fact that they produce more effective shaft horsepower than turbines of other systems. It is an actual fact that in consequence of the high efficiency of the turbines the installations produce a very high effective power, as has been shown by the various tests that have been made.

Now if anything could be said against what I have just pointed out it would be that all this can scarcely be of much value, so long as we have no propellers that are capable of getting practical results out of the high effective horsepower that we are developing. In this regard I would, however, call attention to the fact that investigations have already shown how high we have been able to bring the propeller efficiency, even in propellers with a high number of revolutions. I will acknowledge that in the case of the *Lubeck* this efficiency was still poor; but results were much better with the *Stettin,* for here the efficiency made quite an advance toward that of other vessels. Results were even more favorable in the case of the torpedo boat *G 137*. Nevertheless, we need to continue our efforts along this line. I am convinced that thorough investigations into propeller conditions and into the construction of screws with a high number of revolutions will bring about great progress in this direction, the results of which will be constantly in favor of the divided-turbine arrangement.

That I am not alone in this opinion, I have gathered with much pleasure from the remarks of Geheimrat Flamm, according to which he also is convinced, that with fast-running propellers we shall yet be able to attain much better results than is today the case.

Therefore, gentlemen, I maintain that the divided-turbine installation is the proper one because of its higher efficiency, and that the single-shaft installation is not an improvement upon the other, but shows a retrograde step. It has never yet happened in the history of engineering that we have given up a better efficiency after we have once attained it.

Yet occasion may not be taken from the remarks I have just made for speaking of the greater simplicity of the single-shaft systems. Engineering has always been able in the past to learn from experience how to overcome the various difficulties of construction that have arisen, and I feel at liberty to maintain today that the essential difficulties in the arrangement of turbines in interdependent series have already been overcome. The latest applications of the Parsons turbine, as well in the

two small cruisers *Stettin* and *Dresden* as in the torpedo boat *G 137*, have shown excellent results in this regard and have obtained the highest recognition of their value from those branches of the Navy as have to do with the operation of ships. Indeed, we have been informed by the Secretary of the Navy himself that, for instance, the question of the arrangement of the cruising turbines that has caused so much controversy has no difficulty whatever, that even in maneuvers, when short commands follow each other in rapid succession, the cruising turbines are made use of, or in other words, that in spite of the apparent complications, even when maneuvering, use is made of the cruising turbines in combination with the others.

However, they are not properly intended for such a use as we have just indicated; for the fundamental idea of the cruising turbine is, of course, that they shall be used in connection with the other turbines only when steaming for considerable intervals of time at cruising speed, and not when maneuvering. However, they are used even under the latter conditions when the various maneuvering commands follow each other in rapid succession. Finally, I must repeat in this connection that experience with regard to cruising turbines has been the same with all types of construction. Whether I provide special wheels or a cruising turbine of the Parsons system is quite the same thing in the end. Every system has to make use of this device in order that it may obtain a corresponding economy at low powers. However, this provision of cruising turbines or wheels may be somewhat reduced because of the fact that there is not so strong a need for them as there was at first, and, furthermore, that it has been learned from practical experience how to bring them down to a minimum, while in the first installations considerable caution had to be exercised in this regard.

I repeat, therefore, that I fail to see any advantage or practical gain in the single-shaft turbine systems, because the mechanical efficiency suffers on account of that arrangement, and these other considerations that I have mentioned hold practi-

cally the same for all turbines. However, it would be an error to assume that there is no difference whatever in these regards between a Parsons turbine and one of the other turbines named above. The conditions with regard to the division of the power upon the shafts, the number of revolutions and propeller proportions are quite different in every turbine system.

I would accordingly recommend very earnestly that you take care not to be too modern in your views on this question. (Laughter.) Even in the field of engineering fads play quite an important rôle. But we have seen in this instance as at other times that the fashionable thing is not always the best.

DESCRIPTION OF THE FOUNDRY ON THE *VERMONT* AND ITS WORK.

By W. B. Tardy, Lieutenant, U. S. N.

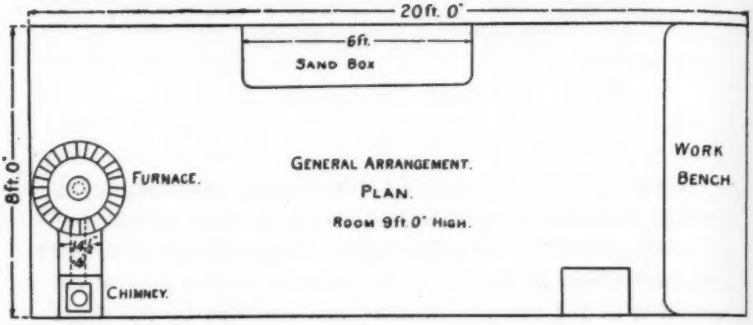
Note.—It may be considered as being something of a novelty to have a practical and successful foundry on board of a fighting vessel. The following contribution from the senior engineer officer of the U. S. S. *Vermont* gives a general description of the foundry installed and operated by the ship's force of the *Vermont*. It is evident that an installation of this character is of great practical utility, and will enable permanent repairs to be completed in many cases where weeks and months might elapse before a certain much-needed casting could be secured from a foundry on shore. The presence of this foundry installation will also save considerable expense for castings which are produced on board ship instead of being supplied from shore.—H. C. D.

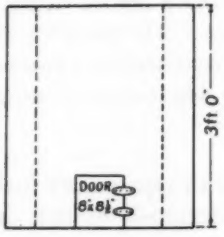
In anticipation of the excessive amount of repair work that might be necessary on a cruise of the magnitude of that of the battleship fleet recently completed, and in view of the fact that the schedule called for two target practices distant from navy yards, it became necessary to improvise some means on board ship of making simple castings.

To this end a search for a suitable space developed the fact that about the only unused space was the exhaust hatch over Nos. 1 and 2 firerooms (dimensions given on accompanying blue print).

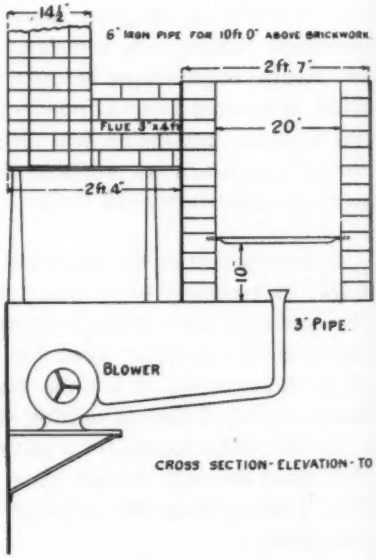
On examination of material on board it appeared that everything needful for the installation of a cupola, except material for smokestack, is carried normally in engineering supplies.

While the ship was taking on ammunition at Tompkinsville,





U.S.S. VERMONT.
FOUNDRY.
As installed by Ship's Force.



Cross Section - Elevation - To Port.

in December, 1907, a steam launch was sent to the Brooklyn Navy Yard to get a 12-foot length of 6-inch iron sewer pipe.

Immediately after sailing from Hampton Roads the blacksmith and a fireman, who by trade had been a molder, with two helpers, began the construction and installation of the cupola and sand box and work bench shown diagrammatically on blue print, which was complete in one week. The material is as follows:

247 fire brick.

50 pounds Portland cement.

1 sheet steel plate ⅛ inch thick, size 36 inches × 72 inches.

32 feet ¾-inch angle iron.

10 feet 2-inch × ½-inch flat iron made into grate bars.

Sufficient asbestos mill board to cover stack and the 12-foot iron sewer pipe above referred to, which was installed for stack.

Lumber sufficient to make a work bench 30 inches × 8 feet, and a sand trough 6 feet long, 3 feet deep, 18 inches across the top, tapering to nothing at the bottom.

The experience during the cruise and since shows that the foundry may be successfully and efficiently run with the following outfit of tools and implements:

2 pair ordinary lifting tongs.
2 shanks.
1 small shovel.
1 small slice bar.
1 small hand tongs (duck bills).
1 riddle (sieve).
1 trowel.
1 spoon slick.
1 small heel slick.
1 corner slick.
1 flange slick.
1 pipe slick.
2 lifters, 1 ¼-inch, 1 ½-inch.
1 pair small bellows.

1 crucible No. 50, capacity 175 pounds.
2 crucibles No. 80, capacity 240 pounds.
6 crucibles No. 20, capacity 60 pounds.

Under normal conditions, making all kinds of castings needed for all departments of the ship, the following material is used:

1 ton Sandusky sand.
1 ton coke.

In addition to the coke a considerable quantity of lump coal is used mixed with the coke.

The draft for the cupola is furnished by ¼-horsepower electric blower, permanently installed, as shown in blue print. This blower is one of those furnished to Equipment Navigation for double-bottom work and is loaned to the Engineering Department.

The incomplete records during the cruise show that, in addition to numerous small fittings cast and machined, the following more important castings were made for the various departments of the ship:

For Steam Engineering.....448 weighing 2,702 pounds.
For Construction and Repair.....231 weighing 1,652 pounds.
For Equipment.....49 weighing 210 pounds.
For Equipment Navigation.....35 weighing 195 pounds.
For Ordnance.....224 weighing 854 pounds.

In addition to this tabular list more than fifty 2-inch Y's, fifty 2-inch elbows, besides a number of T's for voice pipes, were cast and machined and fitted and installed.

This was done at a total cost of $120, exclusive of the wages of the molders; all metal used being scrap, filings, borings, etc., that otherwise would have been thrown overboard.

Since the return of the fleet a dotter boom for each of the twelve turret guns has been made and installed by the ship's force, each boom requiring twelve cast fittings. This work

would have been impossible in the time available but for the foundry.

Also, during the stay of the ship at Boston, two 33-inch, 600-pound gear wheels, together with driving pinions for both, have been cast and machined and fitted in an effort to slow down the train of the after 12-inch turret.

With the facilities on board it was impossible to melt sufficient metal for this large piece of work, therefore the gears were designed as ribbed quadrants, and were cast in four pourings, and then the quadrants were machined and bolted together, after which the gears were cut and the wheels fitted.

The following list will show something of the nature of the castings:

Fittings for voice pipes, including Y's, mouth pieces, elbows and T's.

Deck sockets for stanchions.

Gear wheels of all sizes, for all purposes.

Extensions for sight drums.

Extensions for azimuth plates.

Valves and valve seats, and valve bodies.

Some castings have been made for other ships of the fleet.

T's, elbows, couplings and fittings for all small pipe systems of the ship.

Due to the efficient working of this little foundry, it has been possible to renew all surface and bottom-blow pipes, without buying material or having any of the work done by the shore establishment.

Nearly two years' experience has shown that there is always sufficient scrap on board for all purposes of the foundry, and a careful examination of enlistment records of the engineer's force invariably shows one or more men in various ratings who are molders by trade.

SMALL STEAM TURBINES.

By George A. Orrok, Member A. S. M. E.*

Note.—The development of small steam turbines is of particular interest to the Naval Engineer since their field of application to naval work is not only quite extensive but their application is also possible to many varied uses.

Among the services to which the small turbine has already been applied in the naval service may be mentioned the following:

For driving dynamos.

For driving forced-draft fans.

For driving distiller, circulating and flushing pumps of centrifugal type.

For driving centrifugal air or hot-well pumps in connection dry vacuum systems.

There are numerous other purposes to which this may be applied in the near future; among these the following may be enumerated:

For driving small centrifugal pumps for handling either fresh or salt water.

For fire pumps and for feed pumps.

Turbine air pumps of different types, of which the new Leblanc air pump is an example.

For further discussion of Steam Turbines, consult "Transactions" as follows: Vol. x, p. 680, Notes on Steam Turbines, J. B. Webb; Vol. xvii, p. 81, Steam Turbines, W. F. M. Goss; Vol. xxii, p. 170, Steam Turbines, R. H. Thurston; Vol. xxiv, p. 999, Steam Turbines from the Operating Standpoint, F. A. Waldron; Vol. xxv, p. 1056, The De Laval Steam Turbine, E. S. Lea and E. Meden; Vol. xxv, p. 1041, The Steam Turbine in Modern Engineering, W. L. R. Emmet; Vol. xxv, p. 782, Different Applications of Steam Turbines, A. Rateau; Vol. xxv, p. 716, Some Theoretical and Practical Considerations in Steam Turbine Work, Francis Hodgkinson.

*Read at the Washington Meeting, May, 1909, of the American Society of Mechanical Engineers.

The principal difficulty that has stood in the way of the use of small turbines has been the lack of reasonable economy in small units unless a good vacuum could be obtained for the turbine exhaust. This handicap is being gradually removed, and some of the results given here may certainly be regarded as satisfactory. No doubt the development in this field within the next few years and the competition among the various manufacturers will result in a very material reduction in steam consumption and the adaptation of the small turbine for operating against a back pressure above that of the atmosphere.

The following article, in giving the general characteristics and some particulars concerning the various types of small steam turbines now in the field, performs a valuable service in giving the prospective user and operator of these prime movers a general idea of what these small turbines are, what may be expected from them and to what services they may profitably be put.—**H. C. D.**

The papers upon steam turbines which have been presented before the Society have dealt mainly with the larger types of apparatus and have been written to show the reliability, efficiency and general desirability of this type of prime mover.

2. This paper treats of the smaller sizes of steam turbines from the standpoint of the designing and operating engineer, describing the commercial machines in sufficient detail, with reference to the service to which they have been applied, and giving certain facts concerning their operation which may be of advantage to the engineering profession. Curves of steam consumption are given which show in a general way what may be expected of these machines under certain conditions.

3. At the present time seven machines are on the market and can be obtained in various sizes from 10 H.P. to 300 H.P. with reasonable deliveries. These are the De Laval, Terry, Sturtevant, Bliss, Dake, Curtis and Kerr turbines. Three other machines are nearly at this stage of development and patents have been applied for on several others.

4. Many thousand horsepower of these turbines have been

sold and are in successful commercial service. The following reports of total sales of sizes from 10 H.P. to 300 H.P. have been obtained from the manufacturers:

		Horsepower.
De Laval.....	De Laval Steam Turbine Company..	70,000
Curtis.....	General Electric Company.....	70,000
Terry.....	Terry Steam Turbine Company.....	15,000
Kerr.....	Kerr Turbine Company.....	10,000
Sturtevant.....	B. F. Sturtevant Company.....	
Bliss.....	E. W. Bliss Company.....	
Dake.....	Dake-American Steam Turbine Co..	

5. All of these machines are of the impulse type; that is to say, the steam is expanded in a nozzle and the kinetic energy of the jet is absorbed by passing one or more times through the

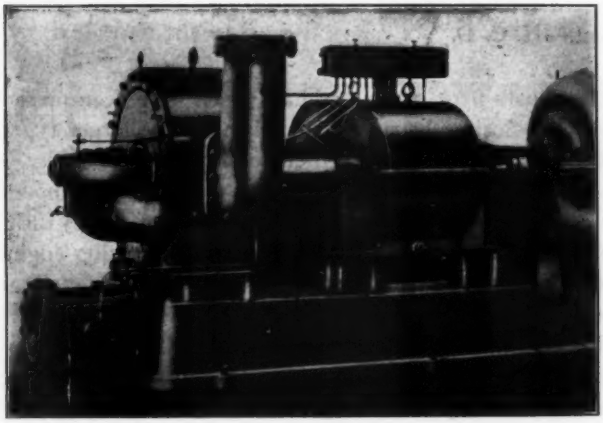


Fig. 1.—High and Low-Pressure De Laval Turbine.

buckets of the turbine rotor. In the De Laval turbine only one moving element and one steam pass are used, which necessitates a very high bucket velocity. In the Terry, Sturtevant, Bliss and Dake turbines a series of return passages is provided. The steam returns two or more times to the same rotor and the bucket speed is much lower. In the Kerr turbine the steam is

used in stages with one bucket wheel in a stage; while in most of the Curtis machines two or three stages are used with two or three rows of moving buckets, separated by stationary guide blades, in each stage. Compound machines of the other types have been made but are not as yet produced commercially.

6. By far the larger number of these machines is used in connection with extra high-speed electric generators, the next larger application being to centrifugal fans for high pressures. Centrifugal pumps adapted to high rotative speeds have been rather generally introduced in the last few years, and it is becoming usual to connect small turbines direct to these machines.

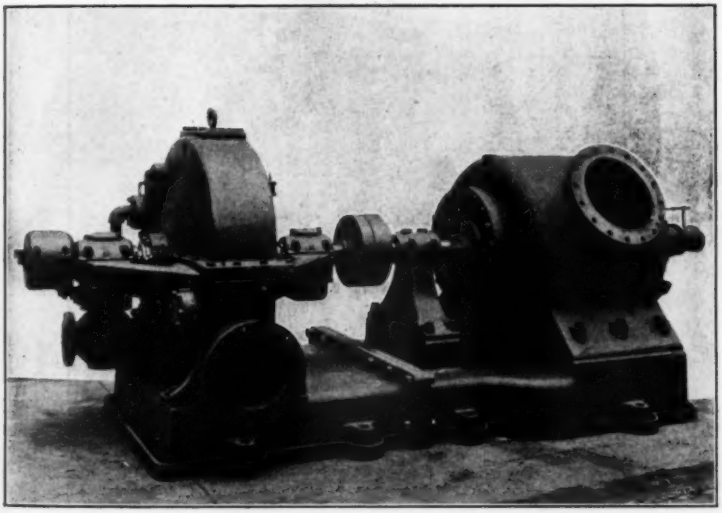


Fig. 2.—TERRY STEAM TURBINE, 36-INCH.

The small space required and the simplicity obtainable in a 100-H.P. turbine at speeds of from 800 to 1,200 r.p.m. has been an important factor in their introduction.

7. The first of the small turbines to be put on the market was the De Laval, made by the De Laval Steam Turbine Company, of Trenton, N. J., and introduced in this country about 1896. This machine is of the pure impulse type; the steam

being expanded in the nozzle down to the exhaust pressure, and the resultant velocity transferred to the wheel in one steam pass. The bucket speed is high, ranging from 600 to 1,300 feet per second. Eight sizes of wheels are made, generating from 10 H.P. to 500 H.P., with one nozzle in the smallest size and eight or more in the 500-H.P. size.

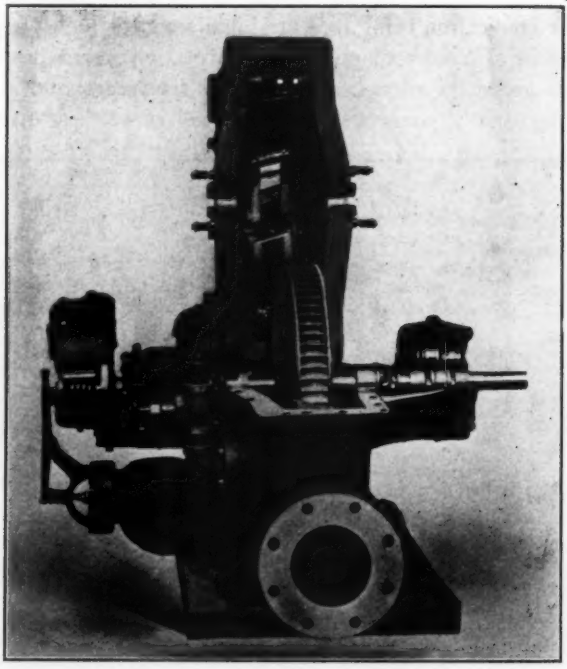


Fig. 3.—Terry Turbine Showing Construction.

8. The high bucket speed necessitates the use of gears of special construction, which have been very successful. The design, construction and economy of this type have been discussed in Vol. XXV of "Transactions," p. 1056.

9. The Terry turbine, made by the Terry Steam Turbine Company, of Hartford, Conn., has been manufactured for about ten years, although the commercial machine has been on

the market only for about four years. This turbine is of the impulse type, but the steam passes through the buckets a number of times before its energy is absorbed. The case of the machine is parted on a horizontal plane through the shaft and at right angles to the wheel. The nozzles and return passes are bolted to the inside of both parts of the casing. The nozzles are in the plane of the side of the wheel. The return passages are of brass and are separated by partitions. The

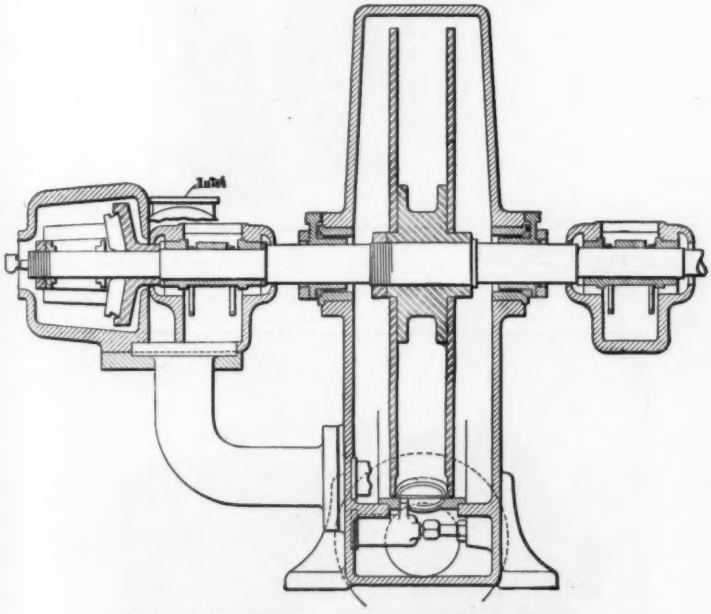


Fig. 4.—Sectional View of Terry Turbine.

wheel itself is built up of two steel discs held together by bolts over a steel center. The buckets are built of steel punchings, fitting in grooves cut in the discs, as shown by the figures. The sizes of wheels manufactured at the present time are 12, 18, 24, 36 and 48-inch, and the number of nozzles varies from two on the 12-inch wheel to eight or ten on the 48-inch wheel.

10. The Sturtevant turbine, made by the B. F. Sturtevant

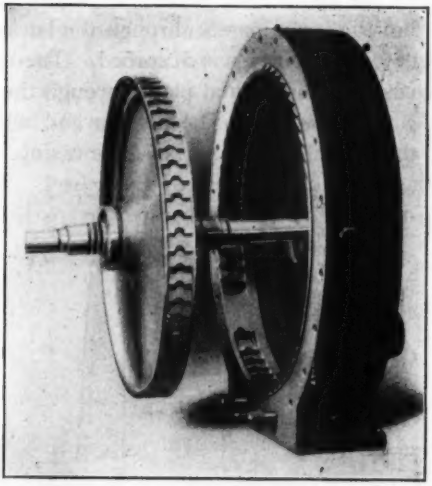


Fig. 5.—Wheel and Casing of Sturtevant Turbine.

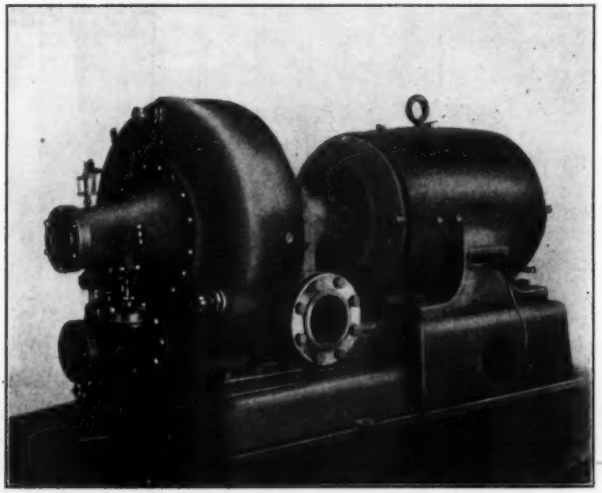


Fig. 6.—Sturtevant Steam Turbine, 30-Inch.

Company, of Hyde Park, Mass., has been in the development stage for three or four years and quite a number of machines have been sold. The present type of turbine may be called "standard," however, and four sizes of wheel are built, 20, 25, 30 and 36-inch, developing from 3 H.P. to 300 H.P. The

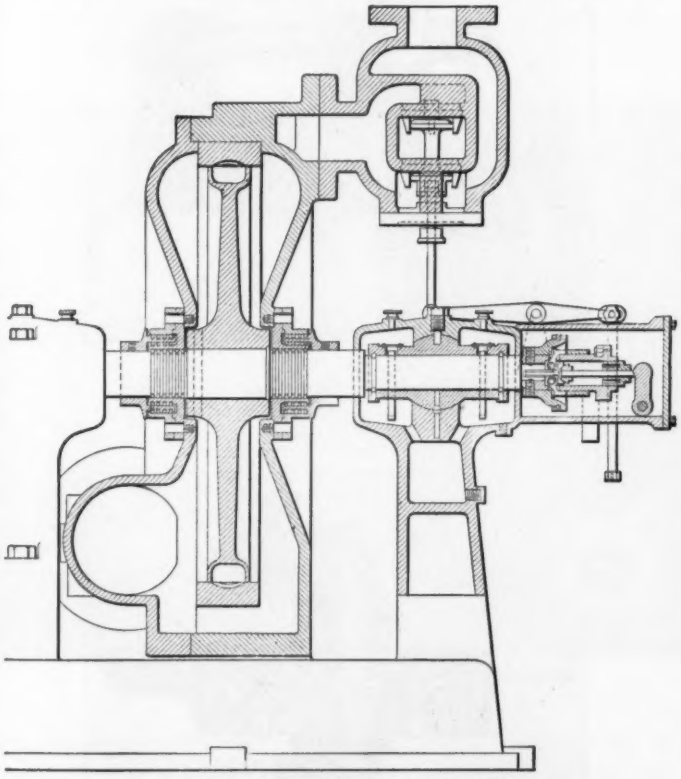


Fig. 7.—Section of Sturtevant Turbine.

turbine is of the multiple-pass type similar to the Riedler-Stumpf. The casing is cast solid with one end. The nozzle and return-chamber ring are inserted from one side and the wheel is milled from the solid. The return passages are from eight to twelve in number and are milled on the inside of the

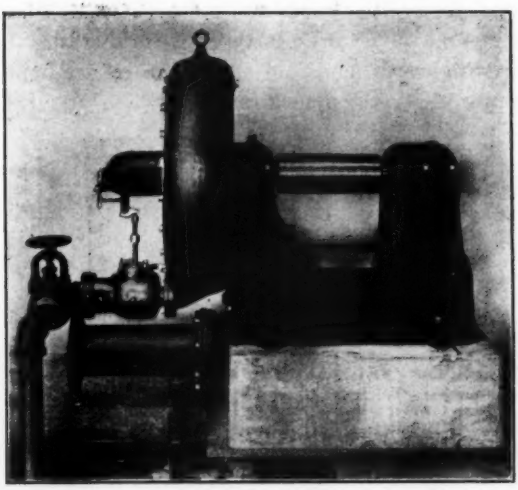


Fig. 8.—Bliss Turbine, 30 Inch.

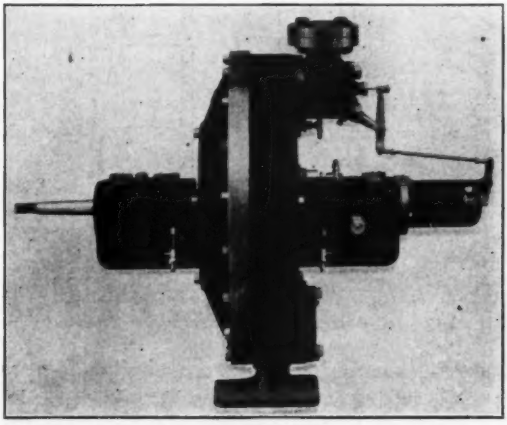


Fig. 9.—Dake Steam Turbine, 24-Inch.

return-chamber ring. They are partitioned and are similar in shape to the buckets. The nozzle lies in the plane of the side of the wheel.

11. The Bliss turbine, formerly known as the American, made by the E. W. Bliss Company, of Brooklyn, N. Y., is of the same type as the Terry and Sturtevant, and has been on the market only a few months. The casing and steam chamber are cast solid with one side and the nozzle and return chambers bolted in. The wheel is milled from a steel casting, or forging in the smaller sizes, and the partitions separating the buckets are inserted and held in place by three bands of steel shrunk on the face of the wheel. The return passages are peculiar in having no partitions. Two sizes of wheel have been built, the 42-inch and 30-inch, but designs have been developed for the 12, 18, 24, 36, 48 and 60-inch, covering powers from 10 H.P. to above 600 H.P.

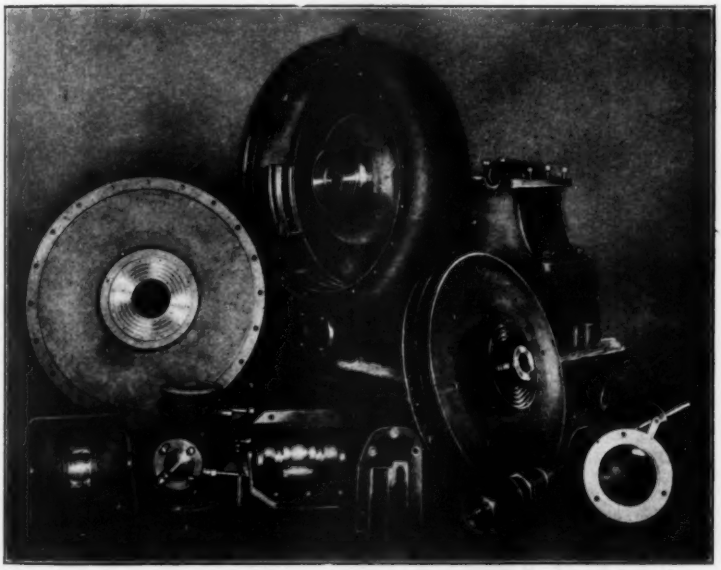


Fig. 10.—Bliss Turbine Dissembled.

12. The Dake turbine, made by the Dake-American Steam Turbine Company, of Grand Rapids, Mich., is a single-stage impulse turbine. The wheel is made of two bucket discs, with milled buckets and inserted partitions, bolted together over a wheel center. In their Headlight turbine the governor is en-

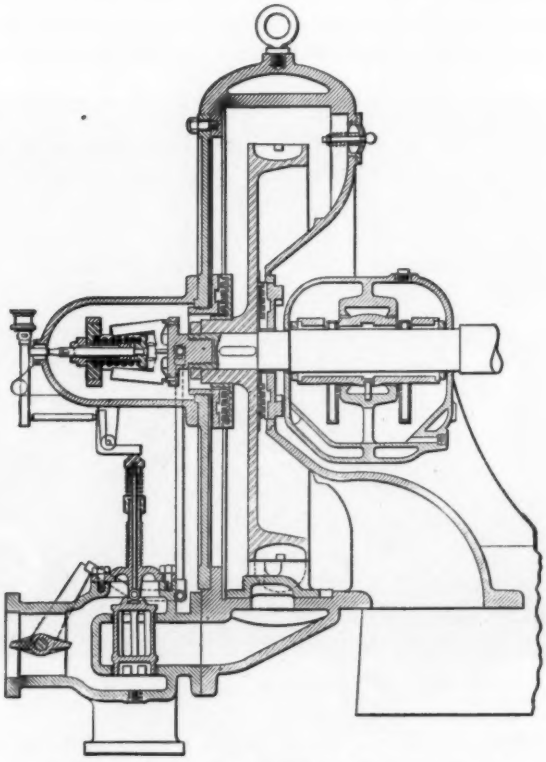


Fig. 11.—Sectional View of Bliss Turbine.

closed between the sides of the wheel. The nozzles and return passages are placed between the bucket discs. The machine is built in sizes of from 5 H.P. to 100 H.P., the diameter of the smallest wheel being 12 inches.

13. Coincident with the development of the large Curtis

turbines the General Electric Company, at their Lynn Works, have developed and placed on the market a line of small generating sets ranging from 5 kw. to 300 kw. This range is covered by eight sizes, the smaller machines being single-stage with two or three passes per stage. The buckets and nozzles are of the well-known Curtis type.

14. The Kerr turbine, made by the Kerr Turbine Company, of Wellsville, N. Y., is of the compound impulse type. It is generally built in from two to eight stages. The buckets are of the double Pelton type, inserted like saw teeth in the wheel disc. Four sizes of wheels, 12, 18, 24 and 36-inch, are made and cover a range of from 10 H.P. to 300 H.P. The nozzles are in the plane of revolution of the wheel and are screwed into the stage partitions and held in place by a lock nut.

15. As in large turbines, details of these small turbines, to which reference has been made, show the skill and knowledge of the designer, and that the same problem may be solved in different ways is well illustrated by the sections here reproduced.

DESCRIPTION OF DETAILS.

16. *Nozzles.*—The diverging nozzle is used by all makers except Kerr, whose multi-stage wheel requires a converging nozzle. In the De Laval, Sturtevant and Kerr turbines, the nozzles are screwed into their seats; that of the Terry is held in place by a bolt. The nozzles of the Curtis, Dake and Bliss turbines are reamed out of the solid. The larger sizes of the De Laval machine which have been put on the market lately have a large number of reamed nozzles instead of the older construction.

17. *Buckets.*—The constructions employed in the Curtis and De Laval wheels are well known and have been described many times. The Terry, Dake, Bliss and Sturtevant buckets are practically semi-circular in form. The Terry bucket is constructed entirely of steel punchings assembled between grooves in the two steel discs forming the sides of the wheel. The Sturtevant wheel is milled out of a steel casting. The

Bliss buckets are milled out, but the partitions are inserted and held in place and steel rings are shrunk on. The Dake buckets are turned out of the solid, the recesses for the partitions milled out and the partitions inserted; the wheel is then bolted together. The Kerr buckets are very similar to the original Pelton buckets and are inserted in the wheel in a manner similar to the De Laval buckets.

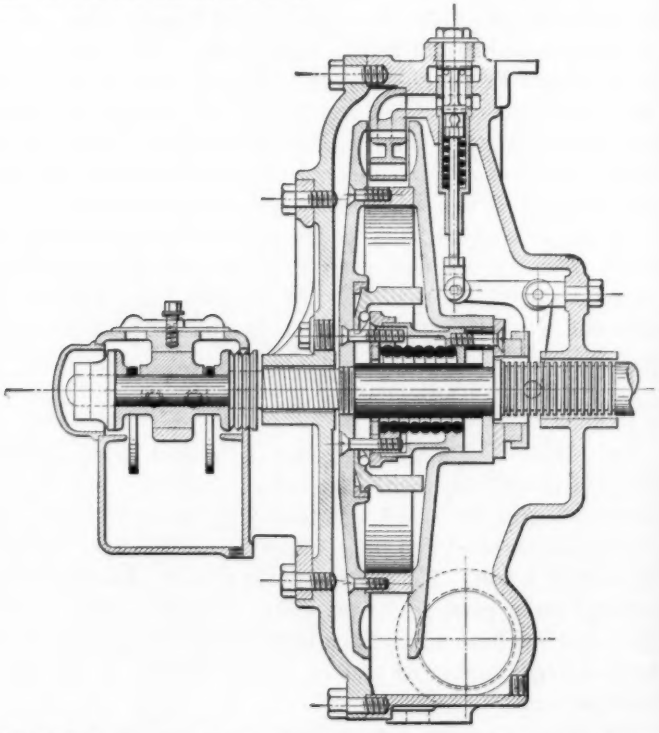


Fig. 12.—Section of Dake Headlight Turbine; Exterior Shown in Fig. 9.

18. *Return Chambers.*—The Sturtevant returns are milled out of the solid ring. Bliss casts them in the nozzle piece and finishes them by hand; Terry casts each one separately, finishes by hand and assembles with bolts; Dake casts the return

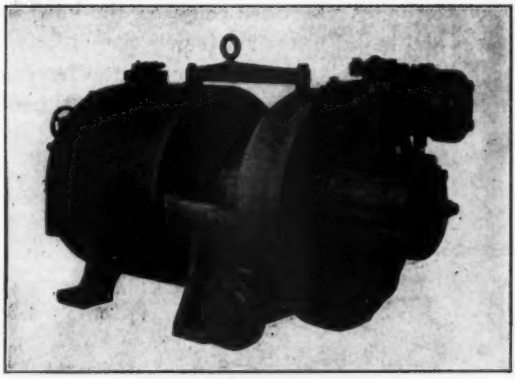


Fig. 13.—Curtis Turbine, 50 H.P.

chambers solid, mills the passages and covers them with a shrouding.

19. *Wheel Centers.*—De Laval, Curtis, Sturtevant and Bliss make the wheel centers of steel castings or forgings integral with the wheel. Terry uses a steel casting but bolts the wheel

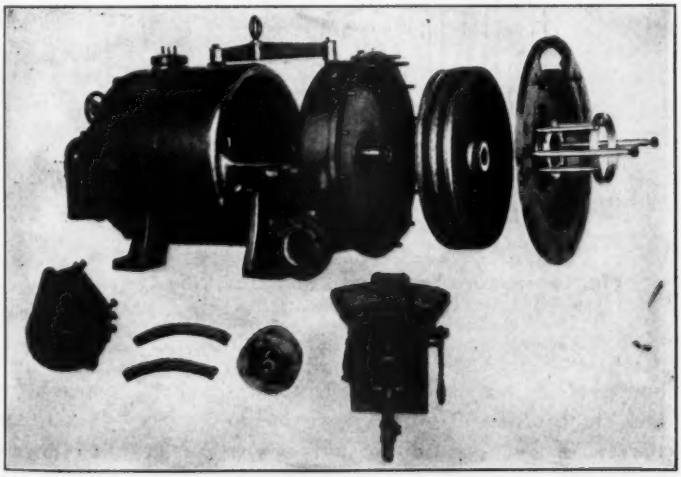


Fig. 14.—Curtis Turbine in Process of Assembly.

disc to it. Kerr uses a screwed coupling, the inner part cut in three pieces and keyed to the shaft with round keys, clamping the wheel disc. Dake's wheel centers are an integral part of the wheel in small sizes, but in the larger machines are steel castings, in some cases a part of the shaft.

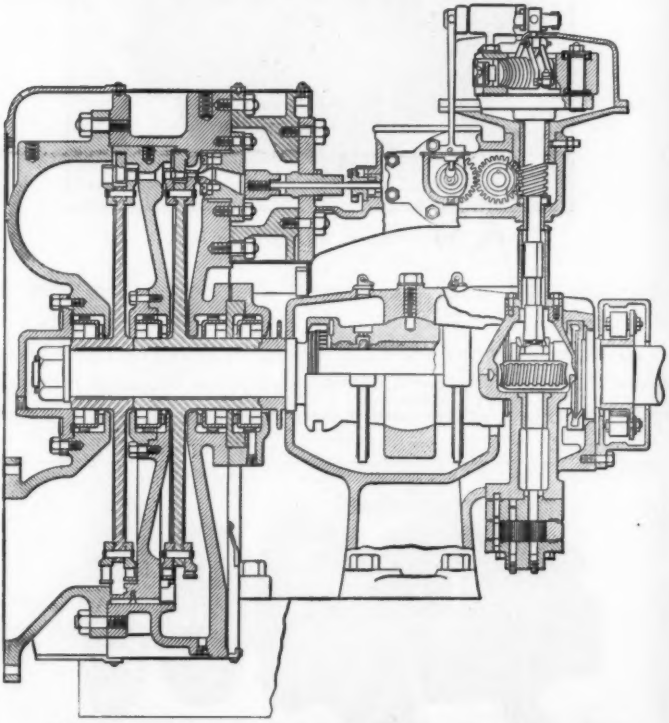


Fig. 15.—Section of Curtis Two-Stage, Non-Condensing Turbine, 160 H.P.

20. *Governors.*—De Laval, Terry, Sturtevant, Bliss, Dake and Kerr use a flyball governor on the shaft end, which actuates the throttle valve through a system of levers. Curtis uses the flyball governor on the shaft for small sizes and slower-speed spring-controlled governors of different forms for the larger sizes. The Sturtevant, Bliss and Curtis machines are

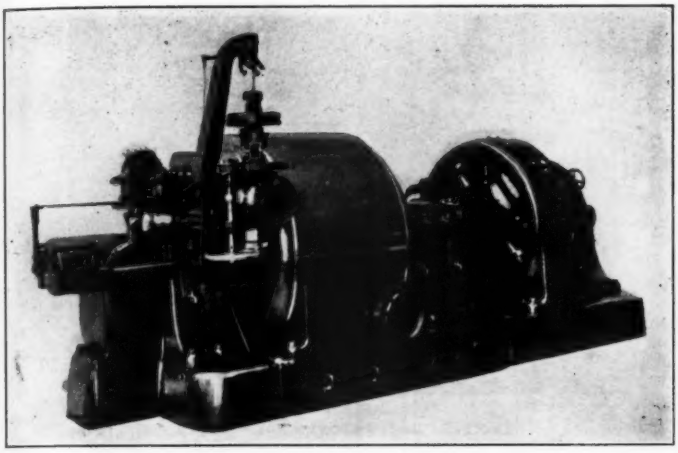


Fig. 16.—CURTIS TURBINE, 200 H.P.

provided with an emergency stop governor as well as the throttling governor.

21. *Glands.*—For non-condensing machines glands are not troublesome, as the difference of pressure between the casing and atmosphere is rarely more than a few pounds. Terry uses a bronze ball-and-socket gland with a long, loose fit on

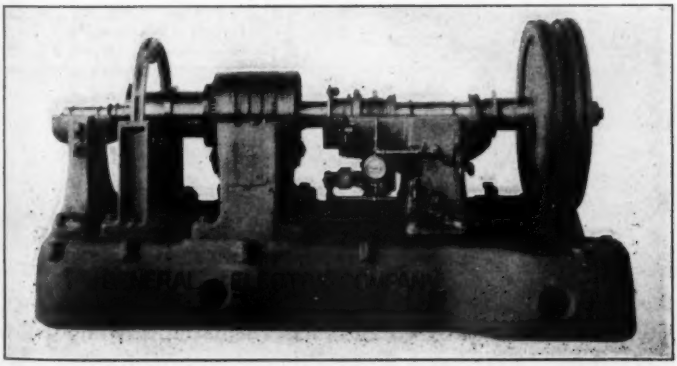


Fig. 17.—REVOLVING ELEMENT OF CURTIS TURBINE IN BEARINGS.

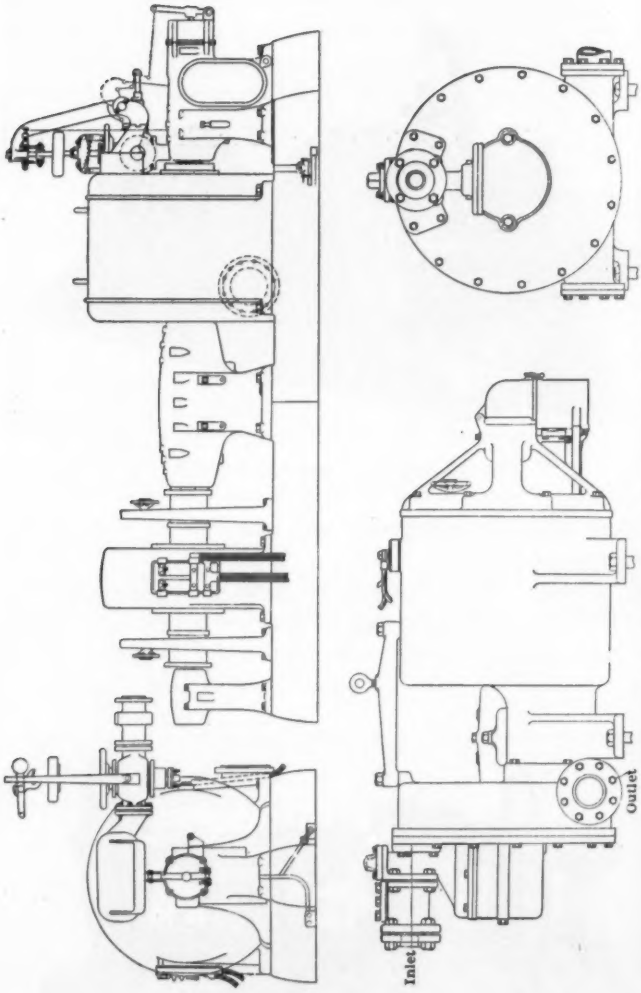


Fig. 18.—Diagrams of Curtis Turbines, 200 H.P. and 50 H.P.

the shaft. Sturtevant and Dake use a set of ring packing, either cast iron or bronze. Bliss has a labyrinth packing without contact. Kerr has a floating bronze bush with soft packing behind it. Curtis uses a metallic packing held in place by

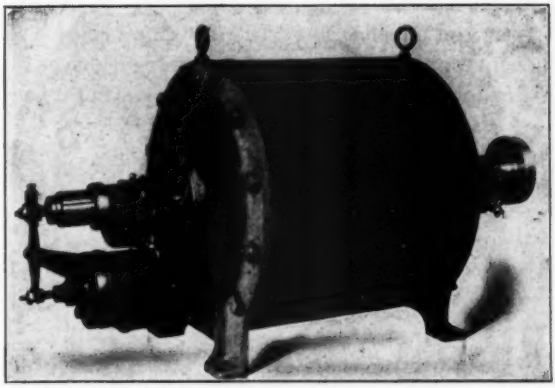


Fig. 19.—KERR TURBINE, 18-INCH.

a gland ring, and for condensing service a carbon-ring packing, steam sealed.

22. *Clearance.*—In none of these machines is clearance an important factor. The clearance between buckets and guide passages on a 24-inch wheel is usually from 1/16 inch to 3/32 inch when hot. Striking or rubbing is practically unknown.

23. *Thrust.*—Theoretically, there should be no thrust in any turbine of these types. Practically, there is always a very small thrust one way or the other. This thrust is usually taken

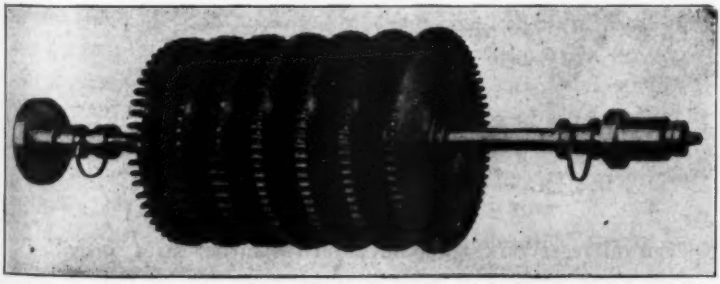


Fig. 20.—COMPLETE ROTATING PART, 18-INCH, 7-STAGE, KERR STEAM TURBINE.

care of by small thrust collars or washers next to the bearings. Thrust from the outside is prevented by the use of a flexible coupling between the turbine and the machine it drives.

24. *Bearings.*—The bearings are always ring oiled with

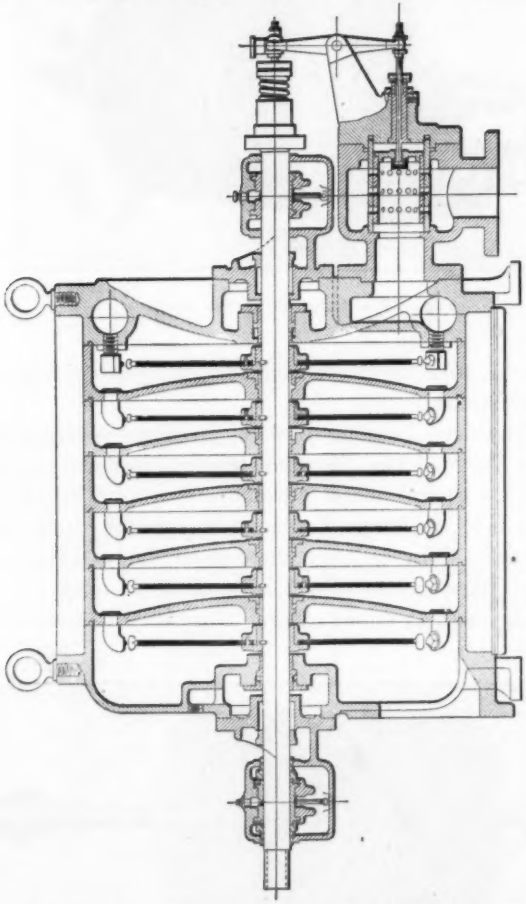


Fig. 21.—Kerr Turbine, Sectional View.

large oil reservoirs, sometimes, on the larger sizes, provided with water jackets or water-cooling pipes for an emergency cold-water circulation. The lubrication of the thrust is obtained at the same time.

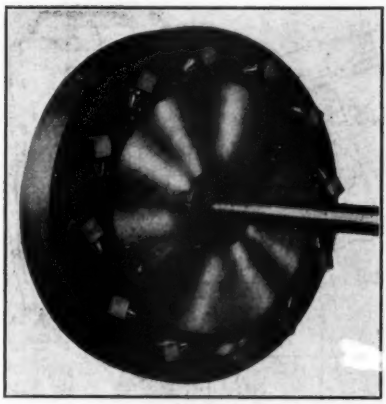


Fig. 22.—One Stage of Kerr Turbine, Showing Nozzles and Wheel.

25. *Operation.*—These machines are nearly automatic in their operation. When the machine is once properly set, the coupling properly adjusted and the bearings supplied with oil, the machine may run for years without an overhauling. The bearings must be looked after to see that no heating takes place and that the ring is carrying the oil to the shaft. The coupling should be examined from time to time to make sure that no thrust is communicated through it to the turbine. With these precautions a three months' continuous run is common, and a number of turbines have to my knowledge run more than eighteen months without a cent spent on them for maintenance. Apparently there is no wear in nozzles, buckets or return chambers. The only wearing parts are the bearings, and these are generously proportioned.

26. These machines may be taken apart and reassembled in half a day; some of them in two hours. The over-hung machines may be overhauled in an ever shorter time.

27. *New Turbines.*—The Hachenberg turbine, made by Wm. Gardam & Son, New York, is a compound impulse turbine resembling in construction the Dow turbine so frequently illustrated twenty years ago. Some experimental machines

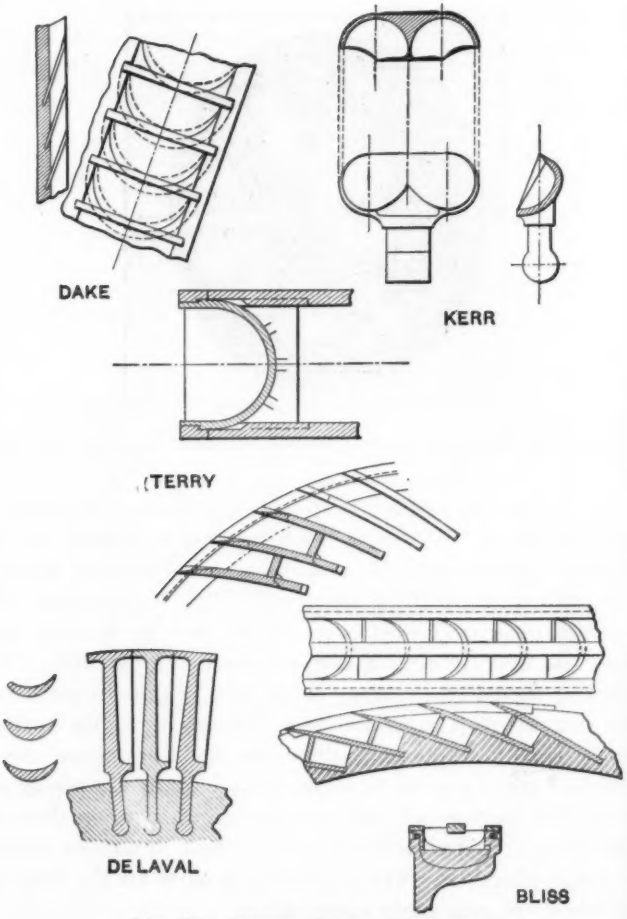


Fig. 23.—TYPICAL TURBINE BUCKETS.

have been built, one of which was tested at Columbia University, and the commercial machine will soon be on the market.

28. James Wilkinson, of Providence, R. I., has a small steam turbine nearly in the commercial stage. A number of these machines are running, and within the next few months it is expected they will be on the market.

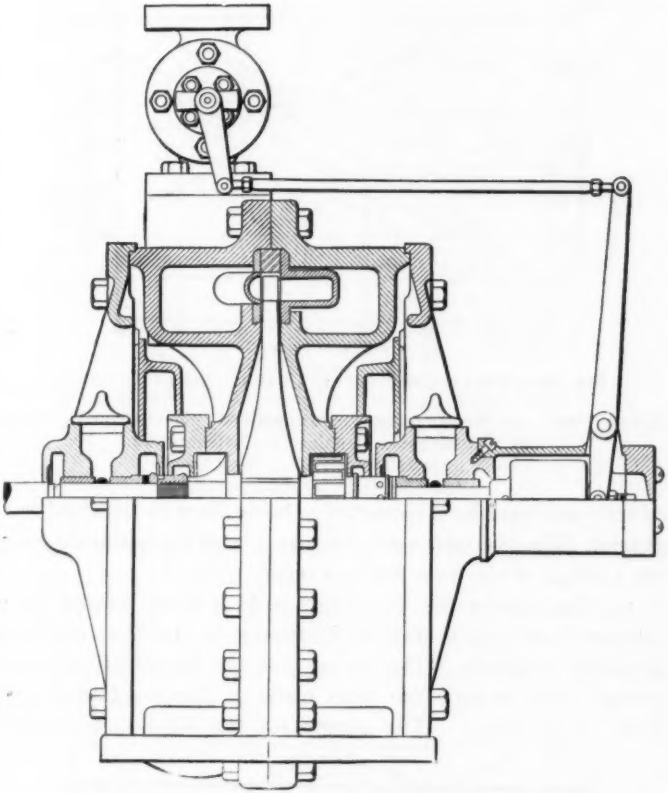


Fig. 24.—Section of Wilkinson Steam Turbine, 20-Inch.

29. The Church turbine, lately completed by the Watson-Stillman Company and tested at Stevens Institute, is another promising turbine.

STEAM ECONOMY.

30. The curves of steam economy have in most cases been obtained from the manufacturers. For the Curtis turbine speed-economy curves are given for the 50 H.P. and 200 H.P. sizes. These curves represent the average of a large number

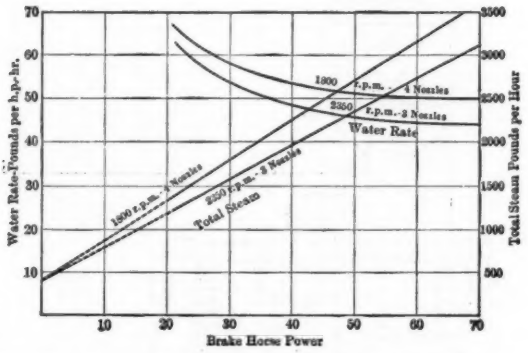


Fig. 25.—STEAM-CONSUMPTION CURVES, TERRY TURBINE.

24-inch wheel, 150 pounds pressure, no superheat, non-condensing, tested by Westinghouse Machine Co., Pittsburg, Pa.

of tests and have been corrected to bring them to standard conditions. The averages were consistent, and the variation from the average in any case was not large.

31. The curves for the Terry turbine were plotted from fourteen tests made at East Pittsburg by the Westinghouse Machine Company. The curves for the Bliss turbine were plotted from twenty-four tests made at Stevens Institute by Prof. F. L. Pryor. The curves for the Kerr turbine were

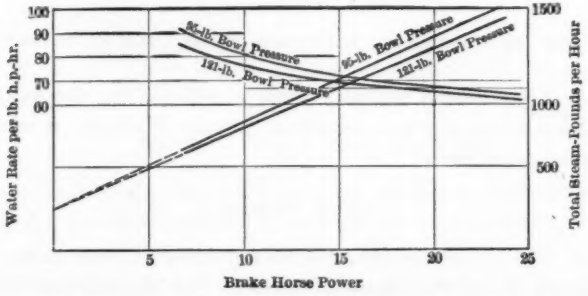


Fig. 26.—STEAM-CONSUMPTION CURVES, STURTEVANT TURBINE.

20-inch wheel, single-stage, non-condensing, 2,400 R.P.M.

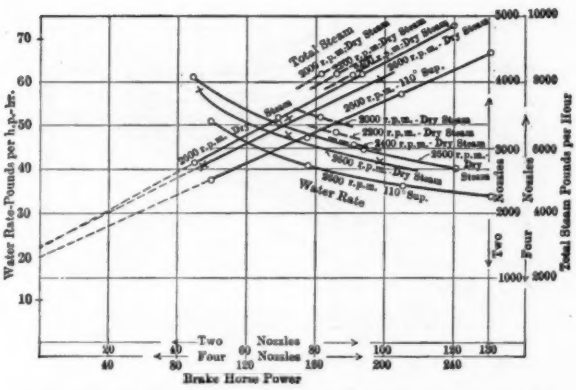


Fig. 27.—STEAM-CONSUMPTION CURVES, BLISS TURBINE, NON-CONDENSING.

Tested by F. L. Pryor, at Hoboken, N. J.
***O*=Two-nozzle, *X*=Four-nozzle.**

plotted from tests made by the Kerr Turbine Company in their testing plant at Wellsville, N. Y.

32. There seems to be no change in steam economy use. It may be too early to make this statement, but machines running regularly for three years have shown no increase in steam consumption.

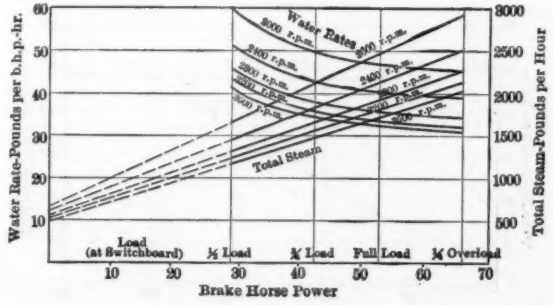


Fig. 28.—STEAM-CONSUMPTION CURVES, 200-H.P. CURTIS TURBINE.

Three-stage, 36-inch wheel, corrected to 165 pounds, absolute, bowl pressure; no superheat, non-condensing.

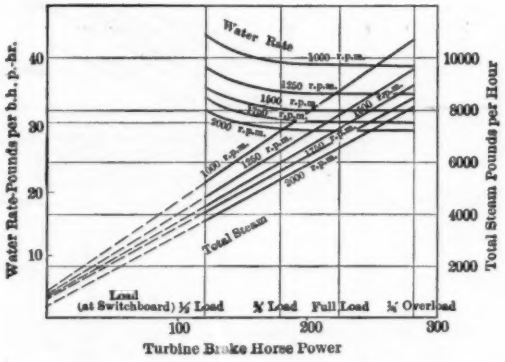


Fig. 29.—STEAM-CONSUMPTION CURVES, 50-H.P. CURTIS TURBINE.

One-pressure stage, three rows of buckets, 25½-inch wheel, curves corrected to 150 pounds bowl pressure; no superheat, atmospheric exhaust.

33. The field of the small steam turbine is somewhat narrow when compared with the high-speed steam engine. The small turbine has its place, however, and, with the development of a more economical machine at the lower speed ranges, will have a much wider field. The turbine-driven centrifugal fan, for both high and low pressures, will have an increasing use, and the centrifugal turbine-driven pumps have marked advantages

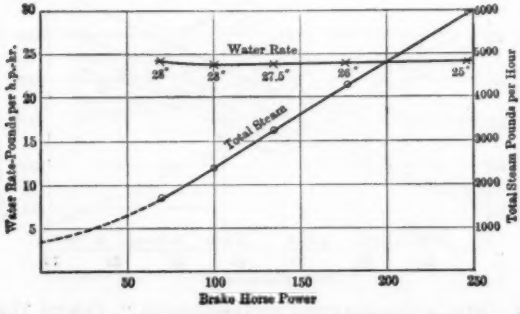


Fig. 30.—STEAM-CONSUMPTION CURVES, 24-INCH KERR TURBINE.

Six-stage condensing, varying vacuum, 70 pounds pressure-gauge.

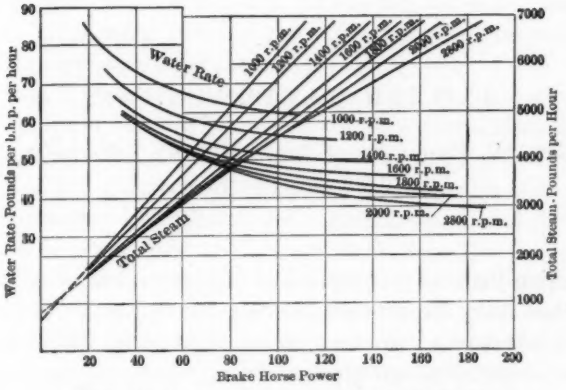


Fig. 31.—LOAD CURVES OF KERR TURBINE.

24-inch wheel, eight-stage, 175 pounds gauge, non-condensing.

over reciprocating apparatus because of the absence of shock on the pipe line and their adaptation to space conditions.

34. The promise of development on these lines has led many manufacturers to enter the small-turbine field and the great expansion of the large-turbine business without doubt presages a like future for the small steam turbine.

ELECTRICALLY-DRIVEN FANS.

By Geo. W. Baird, Rear Admiral, and Formerly Chief Engineer, U. S. N.

During the time the writer was Superintendent of the State, War and Navy Department Building (being then a Chief Engineer) it became a matter of interest to ascertain the amount of power required to operate the electrically-driven fans, and to determine which were the better makes of fans, and to direct the future purchases.

There was, at that time, 380 fans in operation in the building, and the number was gradually increasing. The first fan was installed in 1888, and the purpose was to ventilate the reception room of the Secretary of the Navy. The fan was placed so as to blow out of a circular hole in a window, and was sufficient to keep the air quite pure in that large room. It was a "C.&C." motor, 12 inches in diameter, and it is still in good condition.

The word *ventilation* is a very much misunderstood word. It does not mean motion of air; it does mean change of air. But many employees in that great building used their fans to direct a current of air directly on their bodies, which gives more discomfort than benefit. But gradually they learned to turn the blast in another direction, sometimes against the wall and sometimes along the wall, stirring the air up without changing it. The same thing occurs in halls and lecture rooms, where the air is so laden with the exhalation of the crowd of men as to be offensive; and so long as they *see* the fans moving and *feel* a current of air they believe the apartment is being ventilated; each man has his theory of ventilation and knows which is the best fan for all purposes, and will insist on it with earnestness. The amount of air necessary to preserve the purity of a room may be calculated, and it is sur-

prising how small a fan will handle the necessary amount (about 2,100 cubic feet per hour per capita). The purity is based on the analysis of the air.

If, however, the fan is needed to keep off flies, a ceiling fan of slow speed and small power is the very best and most economical. If a fan is wanted to satisfy the sense of feeling and hearing, then a high-speed fan on a horizontal axis will charm the customer. But, after a while, even the hum and the blast become tiresome, and the sufferer will slow the fan down. With the early fans this was done by putting a lamp in series (to offer resistance); later on, fans were made with resistance boxes in their bases, some having as many as three speeds, but the retarding, it must be remembered, is accomplished by dead resistance: a waste of current and a generator of heat. Among a number of makes of fans I have found but one which has two distinct field windings, with a two-point switch, which enables the operator to employ either speed without interposing dead resistance. This appeared to me important, for I find fully 90 per cent. of the fans in this building are run at a reduced speed the whole day, excepting for perhaps half an hour, when the rooms are being cleaned. Two speeds are desirable, but not imperative. Competition in the trade has led to high velocities, not only for greater delivery of air, but for more economic efficiency. Larger fans, running at lower speeds, are more desirable, but this means a large armature and consequently increased first cost. To ascertain the economic and potential efficiency of some of the fans in the State, War and Navy Building, I conducted some experiments.

As the currents are not projected from the fans parallel to their axis, I placed in front of each a tin cylinder, the same diameter as the fan and about 20 inches long on line of its axis; the fan blades were clear of the cylinder, for the reason that much of the air is drawn in at the periphery. I used a Casella anenometer, in front of the cylinder, to determine the velocity of the air. I found, also, that the velocity varied somewhat at different points, so, to get a fair mean, kept the anenometer moving across the opening. This was done in the different

tests, and if there is any error, it is constant, and is the same for all. An ordinary Weston watt meter and volt meter were used to measure the electric current, and a hand speed gauge was employed to ascertain the revolutions of the fans. The instruments were all of the best of their kind, and I believe they are fairly correct. The C. & C. fan had been in use about eleven years; the Lundell, Crocker-Wheeler and General Electric fans were new; the Holtzer-Cabot fan had been in use about one year. They have all 110-volt motors.

TESTS ON ELECTRICALLY-DRIVEN FANS. 112 VOLTS, DIRECT CURRENT.

Name of fan.	Diameter of fan, in inches.	Number of blades.	Mean pitch of blades, in feet.	Aggregate helicoidal area of the blades, in square feet.	Mean number of revolutions per minute.	Slip of the fan, in per cent. of its speed.	Watts of current consumed.	Cubic feet of air displaced per minute.	Cubic feet of air displaced per minute per watt.
Lundell	16.0	4	1.5	0.736	652.0	6.0	61.0	1,285.0	21.0
Lundell	16.0	4	1.5	.736	781.0	6.0	73.0	1,545.0	21.5
Lundell	16.0	4	1.5	.736	1,163.0	5.7	98.5	2,302.0	23.4
Lundell	12.0	4	.93	.37	975.0	6.0	38.0	645.0	17.0
Lundell	12.0	4	.93	.37	1,358.0	13.5	40.0	857.0	21.4
Lundell	12.0	4	.93	.37	1,725.0	8.0	45.3	1,444.0	31.8
Crocker-Wheeler	16.0	6	1.5	1.05	1,454.0	16.8	92.39	2,538.0	27.61
Crocker-Wheeler	16.0	6	1.5	1.05	1,757.7	16.6	133.0	3,149.6	23.7
Crocker-Wheeler	11.75	6	1.076	.50	1,177.2	12.0	32.0	1,025.0	32.0
Crocker-Wheeler	11.75	6	1.076	.50	1,665.0	11.6	55.0	1,455.0	26.0
General Electric	12.0	4	1.063	.36	745.0	6.0	22.0	589.0	26.0
General Electric	12.0	4	1.063	.36	925.0	4.1	23.0	741.0	32.0
General Electric	12.0	4	1.063	.36	1,285.0	9.0	28.75	970.0	33.0
C. and C.	12.0	6	1.25	.50	554.0	9.0	32.0	552.0	18.1
C. and C.	12.0	6	1.25	.50	1,106.0	6.0	57.0	1,026.6	18.0
C. and C.	12.0	6	1.25	.50	1,500.0	6.0	98.0	1,762.0	18.0
Westinghouse	13.0	4	1.225	.92	473.3	7.0	23.25	473.4	20.5
Westinghouse	13.0	4	1.225	.92	744.4	13.8	36.83	723.3	19.0
Westinghouse	13.0	4	1.225	.92	1,290.0	13.8	56.22	1,253.0	22.3
Holtzer-Cabot	12.0	6	1.427	.45	1,566.0	19.0	78.0	1,409.0	18.0
Holtzer-Cabot	12.0	6	1.427	.45	930.0	20.0	54.0	831.0	15.41
Holtzer-Cabot	12.0	6	1.427	.45	782.0	8.0	47.0	808.0	17.2
Globe	12.0	4	.86	.37	1,283.6	10.0	38.0	696.0	18.3
Globe	12.0	4	.86	.37	1,456.8	21.0	40.0	771.0	19.2

The results in the tables are the means of a number of observations. The volume of air per minute is calculated from the area of the tin cylinder and the observed velocity per anenometer, and shows the capacities of the fans on their relative speeds. The economic efficiency, in the last column, is obtained by dividing the volume of air delivered per minute by the watts consumed.

To ascertain, if possible, how the slip of the blades varied with the surface I reduced the surface of the large Crocker-Wheeler fan by removing first two blades (having two-thirds its surface) and then three blades (having half its original surface). The pitch was constant. The results were as follows:

Watts.	Velocity of air, in feet per minute.	Slip of fan, in per cent of its speed.	Cubic ft. of air per minute per watt.	Surface of the fan, in square feet.
132.0	2,450	7.1	23.7	1.05
110.3	2,337	11.8	29.6	.70
106.6	2,249	16.0	29.5	.525

From this it appears that this slip varies nearly in an inverse ratio with the surface, other things being equal.

The fans were all stripped of their guards before tests. They were not set in the cylinders, but just clear of them, for the reason that much of the supply of air was pulled in at the periphery, and it was desired to give the fans every proper advantage. Each fan was cleaned and balanced before its test, the commutators were smooth, though some of the fans, notably the C. & C., were somewhat worn in their journals. The noise from the Crocker-Wheeler fan increased as its surface was diminished. The spoon-shaped blades were rather more noisy than the straighter blades. In screw propulsion it has been found that a true screw is just as effective as one with an expanding pitch, *cetoris parabus,* and the same is probably true with fans working in air.

In screw propellers we curve the blades backward to counteract the centrifugal force; to prevent throwing the water from the center. With the fan we demonstrate (by the smoke of

a cigar) that current is drawn in at the periphery; in fact, the induction is strong enough to pull a handkerchief tightly up to the guard at the periphery of almost any of the fans.

Though the fans were found to be well balanced, yet there was great discrepancy between the pitches of the blades of even the same fans. Almost invariably the blades have the maximum pitch at the periphery, and the blades near the hub are dragging instead of impelling. This is probably one reason why the velocity of the air at the center of the fan was so diminished. In one case the velocity at the center was 1,193 feet per minute, against 1,922 feet near the periphery. In another case it was 1,407 feet at the center, 2,328 feet halfway between the center and periphery and 2,418 feet at the periphery. My belief is that it would be better to make the same pitch at every helix of a blade, that the motion of the air may be that of perfect translation.

Cheapening the construction of the fans is greatly to be deprecated; scant material and cheap workmanship produce noisy machines, which must soon wear out. The fans are slowed down usually to stop the noise, and at the expense of current. It appears, from this, that the first requisite is a noiseless fan; its economic performance is, in the mind of the average user, quite a secondary consideration.

NAVAL ENGINEERING COMPETITION.

By H. C. Dinger, Lieutenant, U. S. N.

The publication of General Order No. 26, establishing a system of engineering competition in the United States Navy, may be looked upon as a happy omen for the excellence of operating engineering in the Navy and as presaging a thorough development toward practical engineering efficiency and economy as well as having its effects in developing the most practical and fit design of naval machinery.

The order is as follows:

"1. In view of the fact that the efficiency of any vessel in battle is based to a very large extent upon the performance of her engines and their appurtenances, and that her value as a strategical unit is directly dependent upon the economical use of such amount of coal, oil and other similar supplies as is possible for her to carry, the Department has determined to establish yearly competitive steaming contests between battleships, armored cruisers, torpedo boat destroyers and torpedo boats. Owing to the varied duty, steaming under such widely different conditions, with different grades of coal, and to lack of sufficient data to place other vessels of the service on an equal basis for competition, only the above classes of vessels will enter into this, the first competition.

"2. The rules for competitive steaming are laid down to insure fair competition, and must be rigidly adhered to as the first requisite of any successful competition.

"3. In order that progress may be made in this branch of training afloat, it is directed that at the end of each yearly competition each commanding officer and senior engineer officer will submit a report setting forth any methods adopted to increase economy that they may deem worthy of note, and

also any suggestions looking to the improvement of the rules as laid down.

"4. It is strictly forbidden to endeavor to save coal by restricting the use of power necessary for the proper training of the personnel, the general health of the crew and efficiency of the ship.

"5. The standards for the different classes of vessels have been established from experience gained in the past, and from data obtained from past performances of the battleships and armored cruisers; and, while certain ships may be favored in some instances, every effort will be exerted by the Department to adopt such measures in improving the machinery where demonstrated to be necessary in order to even conditions.

"6. The winning vessels will receive suitable trophies, which will be carried for the following year in some conspicuous place, and the name of the vessel with the year she won it will be inscribed on each trophy.

"The Commanding Officer and Engineer Officers of the winning vessels will receive commendatory letters from the Department, copies of which will be filed with their records.

"7. Money prizes will be given to the men of the Engineers' force of the winning vessels as set forth below, but no man not actively engaged on his station in the Engineer Department during one of the full-power trials will be entitled to prize money. Shares are assigned to men of different rating as follows: Chief petty officers, $15.00; Petty officers 1st Class, $10.00; Petty officers 2d or 3d Class, $8.00; Firemen 1st Class, $7.00; Firemen 2d Class, $6.00; Coal passers, $5.00. These prizes are to be paid in the same manner as gunnery prizes, and are to be exempted from checkage by sentence of a summary court martial.

"8. The rules and instructions governing the competitions will be issued by the Department from time to time, and will be considered confidential.

"G. V. L. MEYER,
"Secretary of the Navy."

The establishing of this system of competition shows the realization on the part of our naval authorities of the true import of engineering efficiency to preparedness for war. It shows an appreciation of engineering matters as related to the strategy of war and the need of throwing into this field an adequate share of the activities of our personnel and attention of our officials—some matters not fully realized in the past and which the experience of the cruise around the world served to point out and emphasize.

The system of competition will not only reduce engineering expenditures, as summed up in the cost of fuel, oil, stores and repairs, but it will produce what will be worth much more from a military point of view, the establishment of a positive and practical incentive to the greatest possible development of the engineering designing, constructing and operative efficiency.

An analysis of the effect that this system should have may be of interest and value and may also serve in the manner of suggestion to various lines along which improvement may be brought about.

Primarily the competition creates an interest to realize the highest engineering efficiency on the part of the engineering personnel, and in its development will tend to reflect a true and proper standard of efficiency for which to strive. It also creates an interest in engineering matters on the part of *all the ship's personnel,* even though not directly belonging to the engineering department. It will also serve to put a prompt quietus to the now (happily) fast-disappearing idea, that the engineer department was a necessary evil that had to be put up with.

In its general operation the competitive system, the awarding of the money prizes and the giving of the engineering trophy, will produce a disposition on the part of all on board the ship to create the best conditions for obtaining engineering excellence. Hence it will serve to remove various obstructions sometimes unconsciously placed in the way of securing the best engineering results.

In this there may be mentioned more thoughtful orders from the commanding officer, executive officer and officers of the deck as affecting the engineer department. More definite notice of changes in disposition of machinery, such as time for getting under way, anchoring, advice of probable change in speed and the avoidance of orders for unnecessary changes in speed; prompt notice to allow fires to die out, and permission to begin repairs and more definite knowledge of the time repairs can be prosecuted. Improvement here will show improvement in engineering efficiency. The stopping of wasteful use of steam in orders for working of auxiliary machinery such as fire pumps, blowers, winches, cranes, etc., when not needed and keeping them in operation or with steam on when not necessary will also serve to some appreciable economy.

Two of the principal fields for reduction in steam consumption for auxiliary services are in the use of fresh water and electric current. On a battleship four to six tons of coal a day are consumed to furnish fresh water for ship's use, and a more careful use of the water and a stoppage of waste in the same on the part of the ship's company can easily result in a saving of several tons of coal per day.

The service of electricity is chiefly for lighting and for ventilating. Two to five tons of coal per day are used in this service, and it is very easy to see that the use or nonuse of unnecessary lights and ventilating motors for considerable portions of the day may make a considerable difference in the use of steam for this purpose. That there are large differences in the amount of electric power used and quantity of water used on the same class of vessels doing the same service is easily seen by an examination of their daily logs of performance. This simply shows that some are using more than is necessary. Competition will make for enquiry into the reasons for the discrepancies and will tend to bring them all well on toward the performance of the best one. When there is a special incentive on the part of all to improve the conditions, results are bound to follow.

IMPROVEMENTS IN CARE AND OPERATION.

Competitive conditions will develop an interest on the part of *all* of the engineering personnel to search for the causes that militate against economy and to develop improved methods of operation.

Among these there may be mentioned—

Search for and stopping of steam and water leaks.—Loss due to leakage from joints, drains, leaky valves, etc., may amount directly and indirectly to the consumption of several tons of coal per day, and there is thus here a chance for loss or saving. One of the sources of leakage which is often not appreciated at its proper amount is that through the drain valves of the steam-piping system, either through the valves being left open to blow steam through, leaking valves in the system, or on account of the by-pass valves of the drain traps being left open. As this leakage is not open to view it may reach to very considerable proportions before being stopped.

Another field is the improvement of the vacuum.—A better vacuum both for the main engines and for those auxiliaries whose exhaust is not used on feed heater is a material means for improving the economy. A most common cause for a decrease in vacuum is small, unnoted air leaks in the exhaust piping and air-pump suction piping. In this matter an air leak into condenser or air pump carries with it more serious trouble than does a steam leak. One of the principal sources for air leakage is the L.P. piston and valve rods. This leakage on the main engines could perhaps be largely stopped by making the L.P. stuffing boxes steam packed. This could be effected by running a small pipe from the auxiliary exhaust line to the stuffing boxes. Then any leakage into the condenser would be steam, which can be condensed, and not air, which cannot be condensed, and which by its presence renders portions of the cooling surface inoperative and brings much greater work on the air pump. The discovery and the prevention of these air leaks will call for most searching attention. But when the search for these defects is well developed

many now concealed causes for the defect will no doubt be discovered and remedied.

Another weighty factor as to economy is the operation of the feed-water heater.—This calls for care and attention to see that this device is operating properly. Improper draining of the heater, allowing it to become flooded or air bound, often may prevent the proper feed temperature from being obtained. Careful inquiry into causes for good and bad results will also tend to show up any special defects or advantages in design and construction.

Methods of operating evaporators.—As the distilling plant uses a large proportion of the steam for auxiliaries, improvements in its economical operation may be looked for. One of the most feasible methods of improving economy in this field is to arrange the evaporators so as to work in double effect. The extra piping required for this purpose is almost negligible, and a saving of something like 50 per cent. of coal per water distilled can be made, but the full capacity would be somewhat reduced from that obtained when the evaporators were all evaporated, high pressure. The installation of evaporator feed-water heaters is another step in obtaining more economical distilling apparatus. It is also possible that some arrangements whereby the auxiliary exhaust steam is used for the heating agent may be put on a practical working basis.

The avoidance of an excessive amount of blowing down and care in preventing priming on starting up are matters that must be looked to.

When underway the turning of the make-up feed vapor from evaporators into the auxiliary exhaust when the latter is on feed heater and L.P. receiver may also be used to economical advantage. In such cases priming must not be allowed to take place, and right here the advantage of having efficient separators in the vapor pipe shows up.

The operation of the dynamo plant.—The possible savings in this field come under two heads: First, a reduction in the electric power used, and, second, improvement in the economy of production of the electric current.

The first calls for efficient condition of all the electric-wiring system and motors and general freedom from grounds, unnecessary resistances and losses. A source of wasteful use of electricity sometimes encountered is the running of motors at low speeds when they might be either shut down or operated at near full speed for portions of the time. Most small electric motors, such as for fans, require as much power when operated slow as when going full speed. By a careful examination into the problem it will be found that a considerable portion of the lights ordinarily kept lit can be dispensed with a great deal of the time, and in the same way it will be found that some of the ventilating blowers may be stopped for portions of the day with no hindrance or inconvenience.

Improvement in economical production of electric power is to be found in the efficient condition of the engine, proper tightness of pistons and valves, and proper valve setting; also in the proper operation of their condensing apparatus, so that a good vacuum is maintained. The adoption of turbines for dynamo drive will probably secure a considerable gain in running economy. The fact that the ordinary average use of electric power on a large naval vessel amounts to between 50 and 100 kw. brings up the advisability of providing at least two smaller units of not over 100 kw. for each vessel, in order that the set in operation may be working at somewhere near its capacity. To operate a 200 or 300-kw. unit at a load of 70 or 80 kw. is not likely to give the highest economy. Another thing that this suggests is that these two smaller units be placed in the engine room, where their operation can be looked out for by the engine-room watch, and thus the electrical force could be relieved from watch for large parts of the time and would be available for repair and overhaul.

Firing and training of firemen.—The first loss in the cycle of operation of the steam plant is at the furnace, and hence the manner and method of firing and the training of the firemen is, perhaps, by far the largest field for economical improvement, and the competition will no doubt thoroughly go into this field. Some of the apparatus that will tend toward

better results are the time-firing devices now generally fitted; the use of gas analysis (CO_2 testing outfit) will also add to improvement; but the most important matter is an understanding on the part of the water tenders and firemen of the proper way to handle their fires to get the best results. This calls for training and instruction continuous and never ending, but under such circumstances as will claim the interest of the men and produce a healthy desire on their part to improve both their knowledge and their performance.

The condition of boilers as to cleanliness of the heating surfaces, both inside and outside, will also come to the front, and the problem of how to get them clean and keep them so continuously will absorb attention. This will develop better methods and devices for keeping boilers clean of soot, and will also develop a more careful inquiry into the use of various alkali and boiler compounds tending to find out what will keep dirt and oil from depositing on the inside. No doubt some combination of chemical can be discovered which will have the desired cleaning effect to a very great degree.

The operation of feed pumps.—These pumps are one of the largest steam-using auxiliaries, and for the power developed they are very wasteful of steam. It is now usually the practice to keep an excess pressure in the feed line, allowing the pump to keep the relief valve lifted for large portions of the time. This not only causes the pump to be working against a much higher pressure than may be in the boilers, but it also causes the pump to handle considerable more water than is being pumped into the boilers. By fitting reliable excess feed-pressure automatic-control throttles on these pumps this loss is overcome. These control throttles are designed to keep about 10 per cent. excess feed pressure over the steam pressure. When the feed pressure falls below this the throttle opens and causes the pump to speed up, but as soon as the desired excess pressure is arrived at the throttle begins to close and the pump slows, or stops if necessary. With such governing throttles there is no cause for having the relief valves lifting. They will also serve to bring less severe con-

ditions on the pump, feed-heater piping, etc., and hence will serve to lessen the wear and tear and the repairs to these parts.

The lessening of radiation losses may also serve to add to the economy. The steam piping and cylinders containing steam and hot water are now usually pretty well lagged, but it can usually be found that surfaces, here and there, are bare or not thoroughly clothed. Such parts as the flanges of steam cylinders are usually left bare on the score of accessibility. Temporary and easily-removable covers can be made for many of these surfaces and a considerable number of heat units prevented from escaping.

Manner and methods of overhaul and repair.—The competition will have a special influence in this matter, for when breakdowns are penalized, and where such an event may result in the vessel losing the trophy and the men their prize money, it may be expected that the men engaged in the work of overhauling will take special personal interest to see that the work is done so as to avoid any breakdown. Thus careless work will be avoided and there will be more attention on the part of the men to know and become familiar with proper and durable methods of repair and overhauling. There will also be a more searching enquiry for those responsible for such defects and defective work that may develop. Hence the competition will have a strong tendency for all hands to do their best and also to increase their knowledge and ability to do good work.

EFFECT ON ORGANIZATIONS.

By means of the competition there will also be developed the defects and weak places in the organization of the engineer department and the manner of its administration, and the best means and methods in this field will be singled out to be adopted and followed. It will also bring to notice those methods that get the greatest output and result from a particular body of men. Likewise the weak points, capacities and capability of various individuals will also be brought to special notice.

The requirements for the various portions of the personnel and the manner of their training, etc., will also receive attention, and along with this the methods of rewarding deserving men, the requirements for promotion to the various ratings.

There may also be mentioned the special effect on the individual interest and activity of the members of the enlisted personnel. The man with a practical idea for improvement will have an incentive to develop, and when success meets his suggestion he will be rewarded by the higher opinion of his fellows as well as his superiors. Thus there is developed interest, and this develops knowledge and general efficiency.

Effect upon design.—The more complete searching for defects and keen lookout for results will also have its effect in influencing the design of our naval machinery along the lines and toward the ends that the competition is developed. Some of the particular points to be affected are—

(1) Accessibility for operation and for convenient repair and overhaul.

(2) Producing of a tendency toward durability and reliability in service operation, and in designing for conditions of service and not merely for trial performance.

The penalties for breakdown will bring up and forcibly emphasize defects in design which militate against durability and reliability, and this will thus influence the designing talent in this respect to secure more thoroughly reliable and durable mechanism. This will call for designs of boilers that can be cleaned while steaming and that can be kept in full repair by the ship's force, and a call for engines and auxiliaries that are fully able to stand the hard knocks of service, and, in general, a tendency toward making the accepted design an actual answer to service needs rather than for extremes of theory and the academic conclusions of laboratory experiment without the proper application of service requirements.

Effect on inspection.—As the system of competition will have a tendency to bring forcible notice to any defects in material and workmanship or the manner of erecting the machinery, it will have the effect of producing a better and more

careful inspection of our machinery while building, since, if defects or questionable practice are more likely to be looked for and shown up, more care and attention will be paid to the work of inspection and there will be less of a tendency to pass over any questionable matters while the machinery is being built or repaired.

The competition thus far only contemplates taking into consideration coal and oil consumption, freedom from breakdown and the results of a full-power run. An additional feature that can with great advantage be put in the requirements when the scheme has gotten fully into working form is the general expenses for the engineering repairs and the cost of engineering material required.

Competition in these matters will not only serve to prevent unessential repair work being done, but it will bring out to the full the latent possibilities of the ship's force in doing repair jobs; the development of these possibilities and the lessons to be learned from them in enlarging the sea-keeping qualities and the preparedness for any emergency position of the fleet when called to active service. If a certain repair has once been made by the ship's force, should the same be required again, it can readily be known that the ship's force is capable of doing the job.

The amount of money spent for coal by the Navy afloat is approximately four millions a year; for oil, engineering supplies and material about two millions; for engineering repairs, about two and one-half millions.

As the result of a well-developed system of competition, it is easily believable that one million of this sum can be saved, and with the saving a better general result in engineering efficiency obtained on the vessels where the saving was made. It is not without the bounds of probable possibility that the money saving may be even much more than this.

On the whole, the establishment of this system of engineering competition may be regarded as the most important step that has been taken in recent years for the development of practical service engineering efficiency. And this is the result

that we are finally after as far as relates to the naval engineering, namely, the highest possible engineering efficiency as shown by the performances of the machinery of the fleet in service. The system of competition will have its effect not only in the engine and boiler rooms of the naval vessels, but also in the designing room where the designs are prepared, in the shop where the material is prepared, and at the dock where the machinery is being installed or repaired.

TRANSMISSION OF INTELLIGENCE ON STEAM VESSELS.*

By H. A. Horner, Electrical Engineer, New York Shipbuilding Company.

The following descriptive article should be of particular interest to the members of this Society, since it gives a very complete general description of the methods of transmitting intelligence on naval vessels of late design and also of the instruments and installation employed. This is a subject rarely treated of in the engineering press with any approach to the completeness and detail with which it is here set forth.

A few additional explanatory footnotes have been added.

The article and cuts are reproduced through the courtesy of the Franklin Institute.—H. C. D.

Communication on steam vessels divides itself into signals for navigational protection from other craft and means whereby it may securely provide for its own safe carriage of human life and cargo; on the one hand exterior communication to ward off collision, as well as maintain its own legal course, on the other interior communication for the proper, lawful and safe manipulation of the vessel and the accommodation of her passengers, officers and crew. Exterior communications required by law are: Running and anchor lights, searchlights (in some instances), steam whistle, siren fog whistle, rockets, etc. Wireless telegraphy, submarine signals, night signal sets, electric flashlights for steam whistle are carried on many vessels today as a greater factor of safety. The scope of this paper will not permit even a brief description of these systems, if indeed a brief description could be made, and attention will

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be addressed solely to the reasons for, and the present means of, interior communication on steam vessels.

Electricity holds an important place in the transmission of ships' signals, but this place is secondary as regards the movements of the vessels. Those signals which are necessary to navigation and maneuvering of the vessel are performed mechanically. The control of the main propelling engines from the bridge or pilot house is accomplished by mechanical transmitters connected by bronze wire to receivers in the engine room. Wheels are encased in each instrument traversed by brass chains. To the ends of these chains the bronze wire is attached. Where corners are encountered triple-linked brass chains are led over brass pulleys. In all cases reply signals are transmitted in order that no confusion may arise. The cycle is thus: Pilot house orders full speed ahead. Engine room replies by bringing arrow attached to handle to the same order. This latter is performed before the actual movement is given to the engine. The markings on the dials are usually of the same character, namely: "Stop," "Stand by," "Slow," "Half speed," "Full speed," "Ahead," and the same "Astern." The dials used on naval vessels differ a trifle, thus: "Stop," "Slow," "Half," "Full" on back motion, "Slow," "Half," "Standard," "Full" on ahead motion. The dials of the transmitters for naval vessels, on account of gun shock, are made of a cast-brass framework, with the openings filled in with heavy transparent celluloid. Those for the merchant marine are fitted with white porcelain, the orders filled in with black enamel. They are illuminated by electric or oil lamps of small candlepower. The receivers in the engine room are entirely of brass, with the orders deeply cut in and filled for the "Ahead" and "Stop" divisions with black enamel and on the "Astern" divisions red. The dials of standard transmitters are 12 inches in diameter and receivers about 16 inches in diameter. Smaller-sized machines are recommended only for small craft, such as have pilot houses too small to accommodate the standard sizes.

These instruments naturally superseded the ordinary brass

gong and jingle bell in so much as they were the more readily operated and provided a great reliability. Today steamship rules require and naval vessels carry gongs and jingle bells as auxiliaries to the mechanical telegraphs in case of derangement of the latter. They are also required by law to have a "tube of proper size so arranged as to return the sound of the gong to the pilot house." This practice is justified by experience. The detail as will be clearly recognized is truly serious; for not only is human life endangered, but incalculable damage will result if these signals are not correctly transmitted when docking the vessel.

Working upon the same principles as described above and resembling in outward appearance the engine telegraphs, there are installed on merchant vessels docking, steering, helm and engine-direction telegraphs. Docking and steering telegraphs are usually combined in one instrument. Two handles are employed, one on the right hand and one on the left hand of the head, the dial on one side giving the steering orders in degrees of the helm and on the other side the requisite orders for docking. The two instruments, one located on the navigating bridge and the other aft near the hand-steering wheel, are identical. They are not arranged for reply, but can transmit signals in either direction. The orders for docking are interesting to a landlubber because of their peculiar sailor characteristics, namely: "Stop engines," "Slow ahead," "Slow astern," "Not clear," "All clear," "Heave away," "Slack away," "Hold on," "Let go," "Make fast," "Avast heaving," all expressions which, floating back in memory to the days of the wooden ship of small dimensions, were transmitted through the air by the sonorous voice of the captain, whose orders echoed back from the obedient quartermaster. Today no sound is heard. The scene has lost its dramatic interest.

A band attached directly to the rudder stock indicates in the pilot house or on the bridge the exact angle of the rudder. This is the helm indicator. In like manner the engine-direction indicator is connected to the reversing shaft of the main engine, so

that automatically the signal is transmitted when the engineer sets his engine for the given direction. Docking telegraphs are not in service on naval vessels at the present time, but steering telegraphs, helm indicators and engine-direction indicators are customarily installed. Here electrical telegraphs take the place of the mechanical. They will be described subsequently more in detail.

Voice tubes of brass are required by law as auxiliary to the engine mechanical telegraphs. The law is usually fulfilled on merchant vessels by such communication between the pilot-house bridge and engine room and also between the chief engineer's room and the engine room. On naval vessels the requirements far exceed this and will be treated later. The reliability of the voice tube between the engine room and bridge is altogether shattered by two elements which have not been overcome today, and which, as can plainly be seen, are almost beyond solution * — the internal vibrations and noises of the propelling machinery and the wind whistling down the pipe from the exposed position of the tube on the bridge. For this latter cause swivel mouthpieces have been tried with no appreciable effect; for the former, insulated cushions where the tube attaches to hull have been employed with only greater detriment. Flexible rubber mouthpieces of three or four feet in length are installed at certain termini for convenience and portability.

The steamboat-inspection service makes the telephone a requirement on certain types of vessels. "On all steamers where the distance is more than a hundred and fifty feet between perpendiculars of pilot house and forward part of engine room there shall be communication by means of a telephone between the pilot house and engine room, such telephone to be installed in lieu of a speaking tube." This condition will inevitably arise in vessels where the engines are located far astern or on vessels of unusual length. With the exception of this telephone circuit, all other telephone communication is optional and

* Satisfactory voice tubes have, in numerous instances, been installed, but in many cases voice tubes, due to some defect in installation, are not satisfactory.—H. C. D.

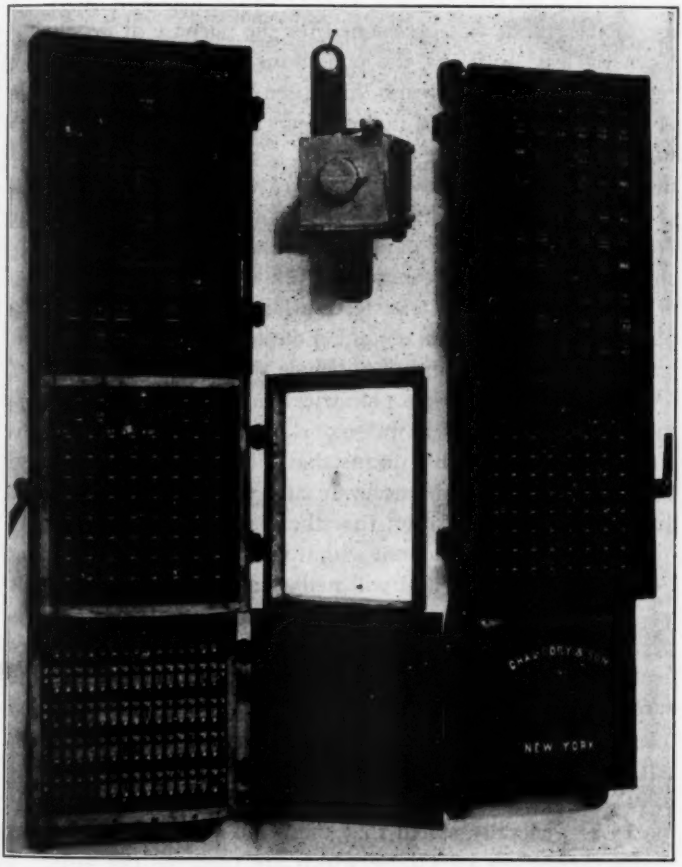
employed only for convenience. The development of the telephone for merchant vessels has not only been curtailed, but almost shattered by the falling off in construction of such vessels in this country. The memory must be strained to recall the last transatlantic steamer of American construction, and coastwise steamers for passengers and freight are few and rare. A glance at American shipping for the last two years will readily convince. The shipyards of the country for this period have been sustained mainly by the Government. An exact description, therefore, of the telephone installed on passenger and freight vessels must be at least vague. Later it will be seen that this important land instrument has been adopted in the United States Navy and a steady development has succeeded. This development work, like many others, has an immediate and intimate effect on the merchant marine. Illustrating this, the writer installed some two years ago on a coastwise passenger steamer eight intercommunicating telephones. These instruments were relied upon to the extent of omitting the mechanical docking and steering telegraphs. They also established convenient communication for the captain and chief engineer. At that time the Navy was experimenting with what is known as the "loud-speaking" telephone (some authorities consider this a well-sounding phrase), which has now been superseded. This type of telephone was adopted for the case in hand. The system, as far as the telephones were concerned, was a common battery, three-wire circuit, other wires naturally being installed for the intercommunicating feature. The telephones for exposed places and where the noises were excessive were entirely enclosed in watertight brass boxes. To exclude external sound as far as possible double-arm receivers, made flexible for convenience, extended from each side of the enclosing case. The non-watertight telephones usually installed in the staterooms had all their parts directly attached and were self-contained. The delicate parts were also encased, but mounted in a hardwood frame. A revolving lever brought the transmitter into circuit. These telephones would in nearly every case reproduce the human voice to such intensity that it

would be audible some six or seven feet away from the instrument. In other large installations of telephones on shipboard recurrence to land practice usually prevails. Switchboards for ordinary land service are installed, and either batteries, or batteries and generators, included therewith. The problems involved will be better understood in viewing the development from a naval standpoint.

As a system of convenience, just as in land practice, the ordinary call bell with push buttons is without a rival. As an adjunct to the voice-tube system it maintains the dignity of its importance, although on many merchant vessels its place is filled by a whistle in the voice-tube mouthpiece. Annunciators resembling those found in offices and hotels are manufactured with a drop of such design that the rolling and vibrations of the vessel will in no way affect their proper and accurate operation. For, above all things, a system of convenience must, as such, work consistently. Despite all the wonders of electricity and all the development by all the mighty minds, if you press a button and there is no result therefrom, you not only become an atheist, but a positive pluperfect anarchist. With push buttons made of watertight pattern, where exposed to the weather or rough usage, with innocuous ones in the better part of the ship and with well-designed annunciators, the call-bell system not only possesses an enviable and convenient position, but also is as indispensable to the comfort of the passengers and officers as the pleasant quarters or the agreeable cuisine.

The distinction between the mechanical instruments used on naval vessels and those employed on merchant ships has been punctuated. There are three systems of such communication that are not ordinarily fitted on the latter type of ships, but which are never omitted from battleships, namely, fireroom telegraphs, blower telegraphs and turret-hoist telegraphs. The principles of their operation and methods of installation remain the same. Turret-hoist signals were only lately changed from electrical to mechanical, due to the sluggishness of the carbon-filament incandescent lamps as compared to the increase in speed of the hoist, the latter lifting the charge from the hand-

ling room to the gun breech in five seconds.* The signals are very simple, to wit: "Hoist," "Lower." The fireroom telegraphs control the management of the firerooms (or boiler



METALLIC THERMOSTAT AND THERMOSTAT ANNUNCIATORS.

rooms). For the accomplishment of this purpose their dials are accordingly designed. They read as follows: "More feed," "All right," "Less feed," "Stop firing," "Priming,"

* Change made due to greater regard for safety and that mechanical signals were regarded as more thoroughly reliable.—H. C. D.

"Stop," "Slow," "Full speed," "Start auxiliary feed," "More steam." In battleships, where the design of the compartments has required that the forced-draft blowers be located at some remote place as regards the fireroom floor, the use of telegraphs was occasioned for the purpose of producing more or less draft, as the conditions might demand. The regular fireroom telegraph has been requisitioned for this object, with naturally its dial readings changed to those which would follow from the application. The signals indicate to the operators at the blowers to increase or decrease the speed of the motors. Electric motors are now the prime movers for these auxiliaries instead of steam engines.* Mechanical gongs and jingle bells for the operation of the anchor-windlass engine, ash hoists and on the transfer platforms of the turrets complete the signals that are not either electrical or electro-mechanical, if the latter classification include the voice-tube system.

To the questions of pure electrical engineering there is augmented on naval vessels the important factor of military efficiency. Expanded, this means that all apparatus must be so designed that it will be accurate and trustworthy under any and all conditions of war; that the material and instruments must withstand shocks from within when the vessel is offering her defense in action and will maintain stolidly the hot shells of her enemy in return. Development on military lines is perforce gradual when the basis of the movement revolves around the theory of battle. War is by good fortune quite rare in these "piping times of peace." But as the wise nation must prepare for war in time of peace, the development work on military lines can advance only by the observation of past naval engagements and sensible deductions from them. It might be generally stated that these interior communications divide themselves into those which are used for the ordinary peaceful movements of the vessel and those which are useful and necessary in time of actual conflict. For the purpose of

* Electric-control devices for operating and regulating F. D. blower motors from the firerooms are also being considered, and will probably be installed in the latest vessels.—H. C. D.

being continually prepared these latter signals are always employed in drill and gun practice. With such accumulation of systems it does occur that certain ones make themselves factors in both cases to such a degree that it would appear that no taxonomy could be assumed. Such systems as the call bells, telephones and voice tubes illustrate this clearly. These systems are just as important in battle service as in peaceful cruising. The following arrangement, though open to question, will be adopted for the purpose of this discussion:

Systems employed for both battle and cruising:*

a. Engine revolution telegraph.
b. Engine shaft-revolution indicator.
c. Steering telegraph.
d. Helm angle indicator.
e. Fireroom timing.
f. Call bell.
  Exposed.
  Unexposed.
g. Voice tube.
h. Telephone.
  General.
  Engine and fireroom.
  Bridge and engine room.
  Battle.

Systems employed during cruising only:
a. Fire alarm.
b. General alarm gong.
c. Anchor handling and boat hour gong.
d. Warning signal.
e. Fuel oil-tank indicator.

Systems employed during battle only:
a. Broadside ammunition hoist.
b. Broadside salvo firing.
c. Turret salvo firing.

* It must be held in mind that these systems are available under all conditions. The writer adopts this classification merely for convenience.

d. Cease firing.
e. Gun firing.
f. Torpedo firing.
g. Gyro indicating.
h. Range and deflection.
i. Local turret-gun-firing indicator.
j. Turret danger zone.

It will be noted that of the systems enumerated nearly 50 per cent. are devoted to the control of the guns. Later it will be brought out that, besides these special systems, the telephone and voice tubes are important factors today in the naval war drama.

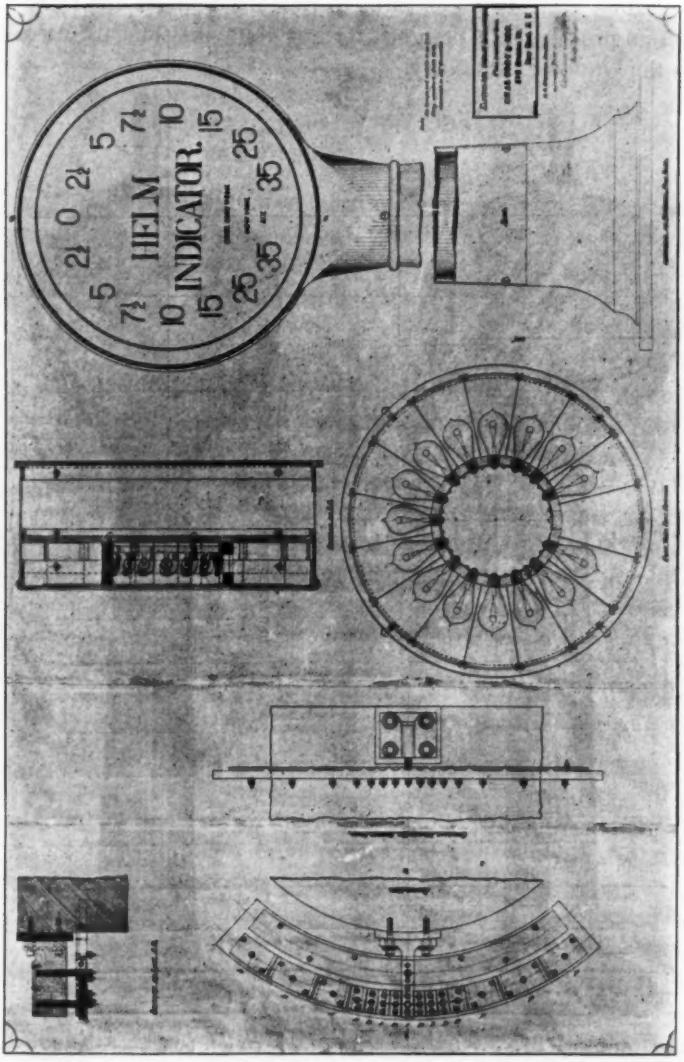
At the present time electric-engine revolution telegraphs, steering telegraphs and helm-angle indicators are designed after the "lamp-pattern" type of instrument. They are identical in their method of wiring and general design, so that a description of one will suffice for all. Engine-revolution telegraphs are designed for the purpose of increasing or decreasing the speed of the vessel during squadron formation.* The vessel being under orders for maintaining standard speed, this being indicated by the mechanical telegraphs, one, two, three or four more revolutions will be signalled by this electrical telegraph. On the bridge the transmitter of the pedestal type, by the operation of moving a handle around the circumference of the head, rings a bell and lights a lamp in the engine room, which latter signal requires the moving of a similar handle on the engine-room indicator to the revolutions desired. This done, the lamp in the transmitter is lighted, giving assurance that the signal has been received and the operation accomplished. The contact maker in the transmitter or indicator consists simply of carbons which are revolved by the handle across insulated copper segments to complete the lamp circuits. The older type of instrument required the rapid movement of

* The adoption of steam turbines for propelling purposes now requires an entirely new design of instrument, due to lack of close control of turbine speeds and increase in propeller revolutions. Therefore these instruments are designed to transmit any number of revolutions. The proposed type is similar to the familiar "carriage call" device.

the handle of the transmitter or indicator for the purpose of operating a magneto-generator to ring the bell, but the latest design provides bells designed for 125 volts, the standard used in the United States Navy.

ENGINE REVOLUTION TRANSMITTER. ELECTRIC-LAMP TYPE.

ENGINE REVOLUTION TRANSMITTER. ELECTRIC-LAMP TYPE WITH DIAL REMOVED.



ELECTRIC HELM INDICATOR AND TRANSMITTER. LAMP TYPE.

In like manner steering telegraphs* of the pedestal and bulkhead type are installed on the bridge, in the steering-engine room, and central station for giving signals, usually in degrees, for the proper maneuvering of the vessel.

The helm indicators are built on the same lines, are located in the same places, and are for purposes of signalling the number of degrees the rudder has been actually moved from the midship line. The indicators are all wired in parallel with the transmitters, but are so arranged with cut-out switches that only those indicators desired may be in service. The transmitter is located near the rudder stock and the contact arm directly attached thereto. Carbon brushes move over insulated segments of copper, which are designed in accordance

ENGINE-SHAFT SPEED INDICATOR.

with the mechanical arc through which the rudder moves. The vital parts of these instruments are enclosed in watertight brass cases, which carry with them sufficient protection from mechanical injury.

Engine-shaft indicators are located in the pilot house and central station, and by direct mechanical attachment to the main engine shaft permit the direction and number of revolutions of the engine to be read at any time. The dials of the indicators, now made of brass, are marked "Ahead" and

* The dials of the steering telegraphs have recently been changed to read as follows: "Amid," "Course," "Steady," "Starboard," "Port," "Meet Her," "Ease Helm," "5 Degrees," "10 Degrees," "15 Degrees," "Standard," "Hard Over."

"Astern." Between these indicators rests a pivoted arrow actuated by a double set of magnets. As these magnets are put into circuit by the transmitter they move the arrow intermittently either to the right or left, marking thus each revolution of the shaft. With a stop watch the revolutions per minute may be easily and quickly noted. The shaft-speed transmitter has received very beneficial development in the past three years. From a device, which was not only very careless in its operation, but so overworked that its parts could not stand the continued strains, there emerges an instrument thoroughly reliable and not apt to lead to the engineer's increase of vocabulary. A worm band is securely fastened to the main shaft, into which engages a worm wheel. This latter by an extension shaft carries and operates the electrical contacts fixed on a drum. The worm wheel revolves once for every ten revolutions of the main shaft, thereby lessening greatly all strains. The electrical contacts can be so arranged that they mark every revolution or any proportional number. The brushes, as in the other instruments, are of carbon.*

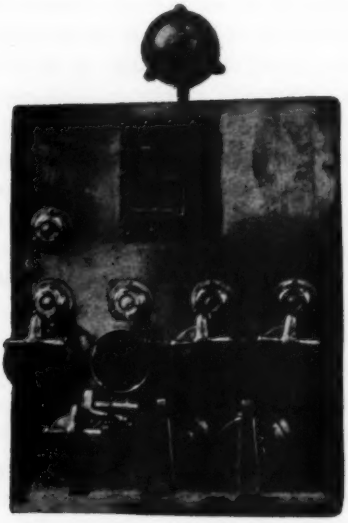
While great improvements are made in important large systems and apparatus, it is remarkable how long crude methods remain by which the desired results are attained. Contractors for battleships are required to demonstrate that the vessel will under certain stipulated conditions acquire and maintain a guaranteed speed. It can be plainly seen that the greatest requisite to meet this condition is sufficient and constant steam pressure. Passing from this stage, the smooth and regular firing of the boilers becomes the point of vital interest for the accomplishment of the result, of interest not only to the builder but as well to the owner, for he also desires that the vessel be capable at all times of producing this guaranteed speed. Until recently the method employed was by word of mouth from the engine room, with men calling off the time intervals from watches, these latter posted in each fireroom. Today these signals are automatically and chronologically regulated and

* This instrument is now to be superseded by a direct-reading instrument, designed to indicate continuously any and all speed changes.

transmitted from the engine room to each fireroom. The transmitter consists essentially of a small motor driving through gear and two steel discs a drum containing on its periphery contact segments. Between the steel discs is placed a rawhide pinion movable from the face of the disc to the center. By varying the position of this pinion the revolutions of the contact drum are controlled. A graduated pointer on the exterior of the watertight case permits the interval of firing from twenty seconds to ten minutes. This transmitter is connected by a cable of wires to the various indicators, one usually in each fireroom. These are designed to produce both aural and visual signals, *i.e.*, a large gong and incandescent lamp. They are about 14 inches in diameter, marked with raised letters "Fire Furnace No. —" above a small opening. In the interior a brass dial cut with the figures of the furnace numbers is revolved by a ratchet movement, accomplished by magnets, as they are energized by the closing of the circuits controlled by the transmitter. In this way the number appears in the opening of the indicator simultaneously with the sounding of the gong. This is the simplest system that has found favor at the present time, although there are others which, being more complicated, still provide the same results.

Employed for use in the officers' quarters the call-bell system is one entirely of comfort and convenience. The various pantries and orderlies are supplied with annunciators connected with push buttons located in the officers' staterooms and offices. This system divides into groups corresponding to the military grouping or rank of the officers. There are calls for the admiral and captain, wardroom calls, junior officers' calls and warrant officers' calls. Since the general change in type of installation from molding to conduit, the design of all annunciators, push buttons and accompanying appliances take the prevailing characteristics of watertightness. The annunciator drops are carefully constructed on the gravity principle, with sufficient safety to protect against false signals due to vibrations or gun shock. The call-bell system, which operates in conjunction with the voice-tube system, is sharply divided for

military safety into exposed and unexposed calls. In such manner the circuits that may be required in the opening of an engagement, and thereby made useless when the conflict rises to its height, will not make unavailable those circuits which in the interior of the vessel are still of vital necessity. It is the practice to duplicate the call, that is, that a push button and bell are required at both ends of the voice tube. As may be surmised, it often transpires that many voice tubes with their calling apparatus meet in one compartment. This leads to a



CALL-BELL AND VOICE-TUBE PANEL.

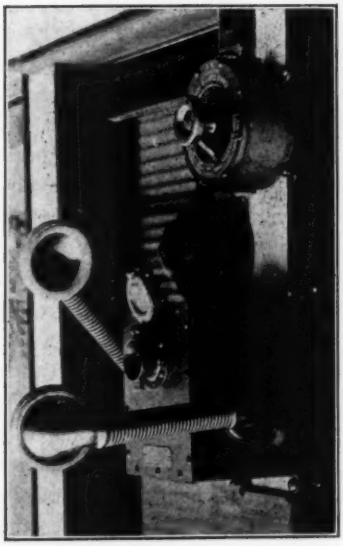
system of stations located at important points throughout the vessel. At these stations it is convenient to group all the voice-tube mouthpieces, push buttons, bells or buzzers and annunciator on a brass panel. This preserves space and produces an excellent installation. The push buttons are all carefully labelled so that communication can be quickly and, with the aid of the annunciator, intelligibly established.

It may be written without fear of contradiction that voice tubes parallel every important system of interior communica-

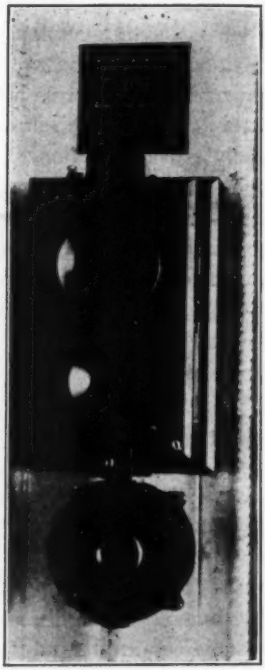
tion. They are seamless, hard-drawn brass tubes varying in external diameter from 1½ to 4 inches. Tubes vary in thickness for the purpose of mechanical strength, those which are led in straight runs No. 20 B.W.G. and those for bends and where subject to mechanical strains No. 14 B.W.G. Where tubes connect two terminal points by a direct path, or of a large diameter, so that they may be utilized for shouting tubes, or when they are employed for gun-firing control, they are not provided with calling arrangements, as above explained. Certain of these tubes are fitted with whistle mouthpieces in lieu of the bell and push button. Mouthpieces differ in design for nearly every condition of use, and only a detailed description could fairly represent and explain them. Indeed, as new conditions arise, or more efficient methods present themselves, the mouthpieces are immediately attacked and the old types ordered into exile. Between compartments that are watertight special mouthpieces of watertight design are installed; between non-watertight compartments, or non-watertight and watertight, a simple covered or open type. For shouting tubes, usually 3 inches or 4 inches in diameter, a design of the pattern of a megaphone is preferred.* In the boiler rooms, where the forced draft occasions a disturbing pressure, the design provided is that of a diaphragm in the mouthpiece, which can be only affected by the human voice. (No longer used.) The tubes used solely for the control of gun fire are arranged so that a long, flexible tube can be plugged into the permanent mouthpiece. This flexible tube ends in a headgear containing in some conditions only two earpieces and in others the addition of a mouthpiece. This design permits the men at the guns to have the freedom of their hands, at the same time receiving direct aural orders from the officer in charge of the guns. It will be observed later how this system has taken its cue from the present adaptation of the telephone for this like duty. To obtain the greatest good from the voice-tube system extreme care is observed in all requirements of its installation. Those points of inefficiency which were indicated in the descrip-

* Mouthpieces are plain, the tube end being bended over; receivers are horn or megaphone shape.—H. C. D.

tion of this system for merchant vessels are overcome as far as possible in naval vessels. The navigating bridge is in most recent designs entirely enclosed, and the voice tube connecting the engine room, irrespective of other considerations, is led in the most direct line to the engine-starting platform. Machinery noises and vibrations are not, to be sure, entirely overcome,



WATER-TIGHT TYPE "LOUD-SPEAKING" TELEPHONE.



NON-WATER-TIGHT TYPE "LOUD-SPEAKING" TELEPHONE.

but every effort is exerted to accomplish the intelligent transmission of the voice. The criterion at the present moment must appear in the abundant and important uses that our Navy finds for their increased employment.

Retrospectively, the development of the telephone on battleships is remarkable. As late as 1903 a few telephones of the

commercial type were installed merely as a matter of experiment. They consisted simply of a box telephone with transmitter and receiver on a hook, such as were prevalent in office buildings, encased in brass for protection in exposed places. Their use was purely a matter of convenience, doubtless little reliance being ascribed to them. The patents covered by the Bell Telephone Company nearing proscription, other parties began experiments for a suitable telephone for marine purposes. The question had not been largely discussed nor experimentation fruitful. However, one observation, that of noises within the vessel, conspired to the design of a telephone which would by its volume, or intensification of the human voice, and by the exclusion of external noises, compass the solution of the problem. This type of telephone was designed, as had been its predecessors, to mount on bulkheads. All portable receivers were discarded and the instrument performed its functions with as little human aid as possible. Double receivers to exclude sounds other than the established circuit would permit were an important adjunct to the watertight type. The non-watertight type, as explained previously, could speak so audibly that it was unnecessary to place the ear to the receiver or to hold the lips near to the transmitter. The receivers were wound for a low resistance, so that the energy necessary was that of a few batteries, usually five. These telephones supplied communication for the general service, and were therefore interconnected as desired by a watertight telephone switchboard located in the central station. This telephone switchboard is interesting. It is still employed. No cords or plugs or jacks can be found on it.* This will probably surprise our telephone engineers. All the interconnections are made by small "throwover" or "tumbler" switches. Other features of the board are recognizable, night bell, visual drops, clearing-out drops, operator's head set, etc. The circuits were divided up into groups of five, which for a forty-line board and the general use of the system on shipboard was found to be ample.

But to return to the telephones. It was early pointed out

* It is the intention to go back to cords and plugs again.—H. C. D.

that though ships' noises did affect the hearing qualities, vibrations transmitted to the various bulkheads acted more to their disparagement and disuse. Coupled with the interferences of the proper hearing qualities came the effect of the packing of the carbon granules in the transmitters. These two salient objections told upon the advantages thought to be realized in this excellently-made telephone and led to the types now specified and installed. No stint of praise should be allowed to the achievement of the "loud-speaking" telephones, for in their passing they have confirmed the telephone for yet greater service — that of controlling the engines of war. So the order was issued that all telephones must be taken off of bulkheads; no more low-resistance receivers; back to the standard voltage in commercial practice and back to a simple two-wire system. From a system depending only on batteries without any intervening coils emerges a system replete with condensers, induction coils, alternating-current ringers, etc. Another step in advance breaks up the whole into four distinct divisions: A general telephone system (ship's service) for the convenience of the officers; a special and independent set of circuits connecting the firerooms and engine rooms (engine and fireroom circuit); another special circuit between the engine room and the bridge (maneuvering circuit); and last, but by far the mightiest, an elaborate system for the control of the guns during battle (fire-control system).

In the officers' staterooms and compartments, where the telephone is not subject to exposure, the hand telephone set, consisting of one transmitter and one receiver, is suspended, when not in use, from a watertight case which contains the condenser and bell mechanism. The act of taking the telephone down for use, or returning it thereafter, automatically operates a switch on the top of the case, which establishes the circuit to the switchboard. The watertight telephone is similar in operation, differing only in that the telephone hand set is enclosed in a stowage box; when this is opened the circuit is established to the switchboard. The telephones connecting the firerooms and engine rooms are like the watertight type used on the

general telephone system, with this difference, that no bells are provided. The system does not pass through the telephone switchboard, and therefore the calling apparatus is taken from the general interior-communication system, consisting of direct-current bells and push buttons. The circuits between the bridge and engine room are direct, as in the latter system, having no connection whatever with the general telephone system. The telephones are exactly the same as those installed for fire-control system. The live wires are brought to a terminal in a brass box, which serves as a permanent fixture wherein to stow the telephone set. A portable twin wire is led to two receivers, wired in multiple, arranged to fit comfortably on the head. By means of a hard-rubber plug and jack cut into the portable twin conductor a breast type of transmitter may be introduced to complete the outfit. This permits the use of the hands and produces continuous communications. The breast transmitter has a vertical adjustment of three inches, a back-and-forward movement of 30 degrees and a side movement of 180 degrees.* Energy is supplied to all of these systems, including the fire-control telephones, through a transfer panel located in the central station. There is further provided for the bridge and engine-telephone circuits a transfer switch, so that the exposed circuit to the bridge may be cut out in case the bridge is destroyed in action, and communication safely maintained from the central station. It would only weary the reader to describe each and every subdivision of battle-telephone system unless he were deeply interested in military questions. Such information he would hardly seek from this paper. As nearly every battleship differs as to her complement of guns, their arrangement or caliber, it is evident that a description of one particular vessel would not apply to others. Suffice it to add, therefore, that in general there will be found a separate and complete system for the guns of large size mounted in turrets; one for the secondary battery (or torpedo-defense guns); one for searchlights, which are necessary for torpedo defense at night; one for torpedo

* Not in new designs.—H. C. D.

firing; and one for the exclusive use of the range officer. The utilization of these battle telephones will be more clearly appreciated when shown later in conjunction with their correlated system of fire control.

Of the systems which are not actually necessary for military operations unquestionably the fire-alarm system is the most important. Until recently metallic thermostats, acting upon the difference of the expansion of two dissimilar metals, were installed in all the coal bunkers, magazines and storerooms; but this type has been found deficient in many ways, and so has been superseded by a simple mercurial type. The circuits from the thermostats are all led to annunciators constructed like those for the call-bell system, having as an auxiliary a switch for each line in order that the bell may be cut out of circuit after an alarm has been given.

The general-alarm gong system, consisting of two or three contact makers and thirty odd 12-inch electric gongs, serves the purpose of calling the crew to drill or arms or giving an alarm in case of danger.

The purpose of anchor handling and boat hour gongs is implied in their names. The gongs are usually 8 inches in diameter, and are actuated by push buttons. The former give directions from the forecastle deck for the control of the anchor-windlass engine; the latter provide a call notice to the officers' quarters that the shore cutter is ready to depart.

A warning is provided for the closing of all watertight doors in cases of collision. The necessity here is for a sound that will be distinguishable from the noises of machinery. The first means devised, and one long used, was that of an electric magnet compressing enough air and allowing it to escape through a shrill whistle. The sound produced greatly resembled the familiar chirp of the cricket. This has now been superseded by what is known as the electric "howler." A magnet actuates a hammer against a tight metal diaphragm, the noise being intensified by a horn such as seen on automobiles. The sound is not as shrill as the whistles, but is sufficiently differentiated from the ship noises to be entirely satisfactory.

In vessels carrying oil for fuel it becomes evident that some indication must be given as to the height of the oil in the tanks when filling same. An ordinary float in the tank provides the switch for closing the necessary circuits. Indications are shown on an annunciator of the ordinary type.

It is essential among the systems purely for the control of the guns that primarily provision be made to quickly handle the ammunition. For the large turret guns it has been explained that mechanical signals are employed. In the case of the secondary battery, although voice tubes allow verbal signals to be transmitted, there has lately been installed a system designated as broadside ammunition-hoist signals. The indicators consist of a simple brass watertight case, with round white disks properly marked and illuminated by 5-candlepower incandescent lamps. The markings provide for signals to hoist, lower and stop, as well as to determine the kind of ammunition desired. Transmitters consist of several standard switches mounted in one case and properly designated. As a check a similar indicator is installed at the loading end of the hoist and the lamps wired in parallel, the transmitter with indicator being located at the upper or receiving end of the hoist.

In order that the turret guns and secondary battery may fire a broadside simultaneously, systems of bells, buzzers and contact makers have been designed. These systems have been nominated, respectively, for the turret guns — turret salvo firing, and for the smaller guns — broadside salvo firing. Small 3-inch electric bells are permanently installed in and about the guns, so as to be distinctly audible; they give the order to "Stand by." Portable buzzers strapped to the chests of the gunners are operated by push buttons and give the signal to "Fire." The contact makers and push buttons are located at the two principal fighting tops and the substations. The point interesting to note in this system is that of strapping the buzzers to the gunners. This is done in order that there can be no mistake in the interpretation of the signals, for, though it may not be audible, the vibrations of the buzzer will be communicated to the body.

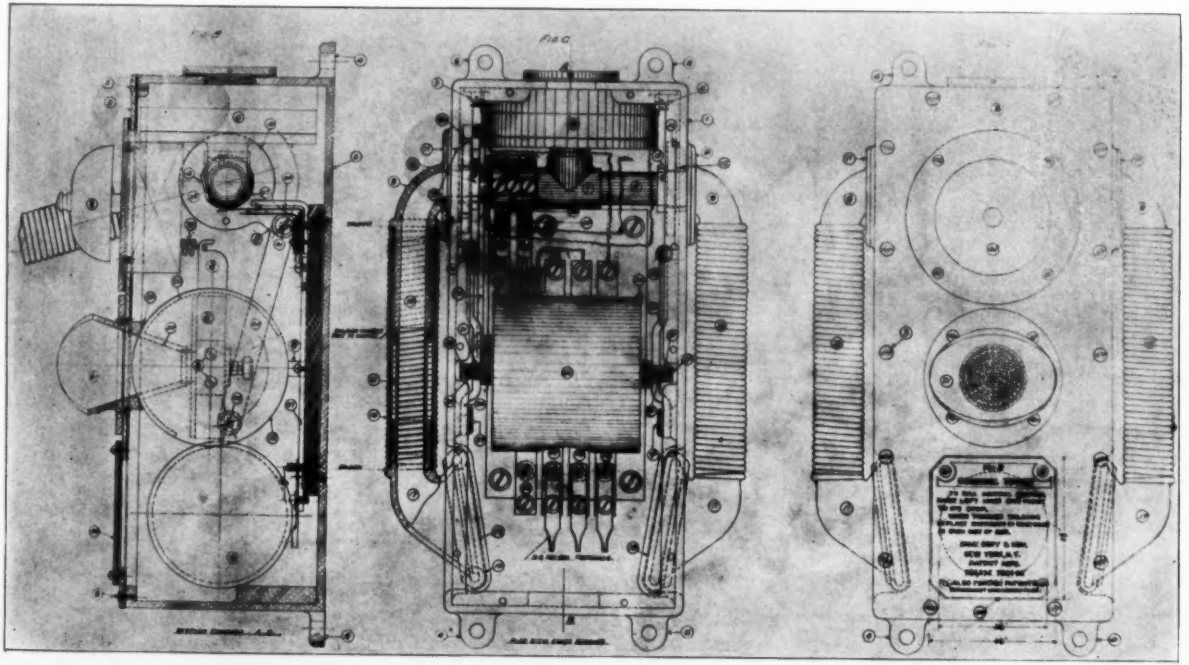
The cease-firing system is identical to the general-alarm system. The diameter of the gongs for this system is made 10 inches instead of 12 inches. On some battleships, in order to better differentiate the sound, one system will have vibratory gongs, the other single-stroke. This system provides signals to cease firing. Thus it is a general gun signal.

At the present writing the actual electric firing of the guns from the vessel's electric plant has never been required. The guns are provided with a local battery system, and the consideration today is not only to retain this means, but also to provide a similar system taken from the vessel's permanent installation. Special motor generators are to be designed so that only the requisite voltage and current will be delivered to the guns. Switches of a portable type, receptacles for connection at the guns and other necessary appliances will be furnished. No details have yet been considered, and it is problematical whether such a system will not in the end find much objection in the opinion of those vitally concerned.*

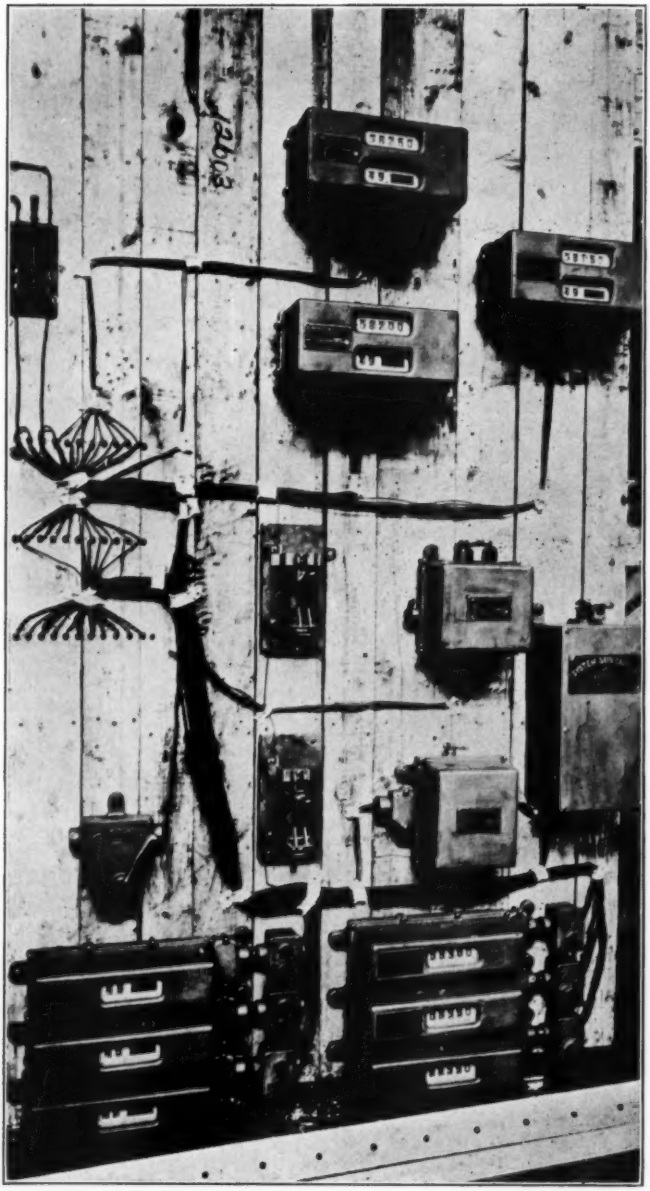
Morale in warfare is an important factor. The enemy must be more or less affected by what he estimates as the fighting strength of his opponent, or what the latter may hold in reserve as reinforcement. So there are retained in our large battleships at least two torpedo tubes. From stations located on the superstructure deck the firing of the torpedoes is not only directed, but actually accomplished. Firing keys, not unlike telegraph keys, are located at these firing stations in conjunction with signals that permit no complication before the firing keys are actuated.

To give the necessary directive action to the torpedoes a system of telegraph indicators and transmitters of the lamp pattern, as described under the head of electric-engine revolution and electric-steering telegraphs, is installed — one transmitter at each torpedo-firing station, with indicators at each torpedo tube. These transmitters indicate at the torpedo tubes the number of degrees from zero center reading to 90 degrees port and starboard. This system bears the natural title of the

* This has been installed in all battleship gun-firing systems.—H. C. D.



EXTERNAL AND INTERNAL VIEW, "LOUD-SPEAKING" TELEPHONE. WATER-TIGHT TYPE.



Assembly of Fire-Control Instruments.

gyro-indicator system, as by this means the torpedo gyroscope is so adjusted.

Of all essential matters in battleship design that of properly controlling the fire of the guns is without question the most important. A battleship is primarily a fighting machine, and therefore the necessity of so controlling the gun fire as to obtain the greatest battle efficiency. This subject of fire control has called forth every consideration by the naval authorities, and investigation, experiment and money have not been spared in providing the most reliable systems suggested. Every idea that was worthy a passing notice has been given due trial, and the liberal spirit of the Government today would gladly respond to any suggestions whereby greater improvements would result. To clearly understand the arrangements now provided on the latest battleship designs some reference must be made to the arrangement of compartments and the disposition of the guns. The design of recent battleships has been rightly dubbed the "all big-gun" type. Our most powerful battleships, those of over 21,000 tons displacement, carry five turrets, containing two 12-inch guns in each turret. Two are located forward, one raised slightly above the other, and three aft, two on the same level and one slightly raised above them. The 5-inch guns used for defense against the attacks of torpedo boats are distributed at important points on the gun deck. The range, deflection and battle orders for these guns are communicated solely by telephones, as referred to in the description of the telephone system. Not only are the 12-inch turret guns supplied with telephones for this purpose, but also with special instruments for visually presenting the range, deflection and battle orders continuously before the sight setters and gun trainers.

The orders all emanate from what are called substations, compartments well below the protective deck and water line, sheltered in every possible way from hostile shell. The range-finding instruments are located in lofty towers, one forward and one aft, with their respective "spotters" and range officers. The spotters, watching each shot as it falls and gauging the

range and deflection, communicate directly with the substations by means of the telephone. The range and deflection transmitters in the substations are immediately called into operation and in turn send forth to each gun the proper order. The problem contains another factor. In naval warfare both parties to the conflict are in motion, and by virtue thereof the range is constantly varying. For this condition there is provided in the substations a range clock carrying a rate-of-change disc, by means of which the rate of change of range may at all times be marked. This range clock has a maximum reading of 14,000 yards. When the shot spotter reports from the fire-control tower, the rate of change of range is set on the clock. The clock continues then to mark off regular ranges which, through the proper official, are then communicated by the range transmitters to the guns. Deflections are noted by the same shot spotter and in the same way transmitted through the substation to the guns. Deflections are measured in yards up to a maximum of 100. Formerly zero was arbitrarily taken at the center, which required the further designation of right or left deflection. By assuming 50 yards as the zero deflection, any number below 50 indicates right and any number above 50 indicates left deflection.

The cause for all this care in firing guns originates from the desideratum of "bunching" the hits. When several guns are firing, particularly in range and their shots are dispersed, poor hitting ensues. Therefore such fire-control systems are important and necessary in that they maintain all the sights of the guns set alike while in the act of firing. Two systems for accomplishing this requirement have been experimented with and have shown about equal advantage and disadvantage from a practical standpoint. It is unnecessary to elaborate a description of either system. Suffice it to say that one system is designed on the simple incandescent-lamp principle, and the other on a system of magnets in conjunction with ratchet-motion escapements. In the former indications are produced by illuminating numbers by 5-candlepower lamps; in the latter the range and deflection numbers revolve by increments of 50

yards for range and unit increments for deflection. The latter instruments, though rectangular instead of round, resemble in their movements the familiar fare registers which are seen in all trolley cars. This system provides also for the repetition of the signal after it has been conveyed to the gun at the sending station. Ready means are also provided for cutting out the instruments which may become deranged without affecting the other instruments on the system. This reply or checking feature is convincingly accomplished in the lamp-pattern design by introducing similar indicators at the sending station connected in parallel with the indicators at the guns. The transmitters in both systems, though the instruments are dissimilar in outward design, are in principal merely switches for closing the desired circuits. The essential difference between the lamp-pattern and the electro-magnet systems is that the former is purely an electric-contact method and the latter an electro-mechanical movement.

The vital importance which attaches to this fire-control system is shown by the regard with which it is installed. With all these instruments located behind and below armor, in the event that the fire-control towers be completely demolished, communication can be transmitted from the captain's battle station, which is a small elliptical armored compartment on the superstructure deck. If, again, by any chance this citadel be destroyed, retirement to the substation is offered. This latter place can only be made untenable by the sinking of the vessel. When this happens the hull becomes only a hulk and the engine-of-war becomes a derelict.

The last two systems in this classification, namely, local turret gun-firing indicator system and turret danger-zone system, may consistently be considered together. They have been required mainly because today it is thought one system cannot accomplish all that is desired. And certainly a detailed investigation will convince even the most conscientious designer that a division was absolutely unavoidable. It has been stated that in the "all big-gun" design the turrets are disposed, two forward, one above the other, and three aft, two on the same

level and one above them. With this alone in mind it becomes apparent that unless due provision is made there will occur in time of war, or target practice, exceedingly dangerous interferences, not only by the various positions of the guns, but also by the turrets which carry them. Casually, the suggestion would be to guard the turrets and guns by positive mechanical blocking devices; but this is impractical inasmuch as it restricts to an alarming extent the radius of gun action, a restriction which would reduce the efficiency of the fighting qualities of the vessel to a mere show in battle. The guns have a certain radius of elevation and depression, just as the turret has a fixed radius of train on a horizontal plane. One gun or set of guns in one turret, let it be the raised turret, are set for extreme depression, while the guns in the lower turret are fixed at maximum elevation on the same degree of train. If under these conditions the raised turret guns are fired, they throw their charge with disastrous results at the lower turret guns. A change in train of the raised or lower turret would avoid any such mishap. Here it must be understood that the turret gunners are excluded from external view, hemmed in behind twelve inches of armor. The sighting of the guns is accomplished by prismatic telescopes, which present to the sight setters the image of the object upon which they fire. Augment the many interferences which will arise by the above illustration by the movement of one turret body into the fighting line of an adjacent turret, and the problem is not only magnified to the extremity of hopeless solution, but becomes utterly exasperating. No instruments for this system have at the present time been manufactured. Designs have been drafted in accord with models of guns and turrets prepared to illustrate the many dangerous interferences. It remains for experimentation and actual trial to demonstrate the need or practical usefulness of a system which perforce must carry with it complications proportional with the results to be obtained. Several methods have been suggested; but to the writer's knowledge only one system has found acceptance at the present time. The principle of the design is based on the

desire to eliminate at least as much as possible the use of small shafting and permit the signals to be conveyed by electric currents. Yet the method must introduce the mechanical feature, because the every motion of one gun and one turret must be transmitted to each of the other turrets or guns where interferences may occur. The system comprises two sets of instruments, one set based on purely the lamp-signal system — the transmitter mechanically attached to the gun or turret, and similar, save in size and number of contacts, to the other electrical telegraphs — and the other based on a magnet floating in a circumferential group of magnet coils whose poles alternately present a north pole and then a south pole. This, producing a revolving motion in accord with a mechanically-operated contact maker, attached either to a gun or turret, reproduces the movement in another turret. The principle is here briefly stated. The details are not conclusively prepared at present; but the object of accomplishing this work by electrical methods rather than by mechanical are at least set forth. If reliability is found to be more necessary than space, weight and inconvenience, then the mechanical system will prevail. Thus the entire success of the turret danger-zone system must await the final verdict of the future.

Many times during the explanation of the above systems mention has been made of the central station. This compartment is located below the protective deck and covered from danger by armor. Besides furnishing a protected station from which to guide the vessel when the upper pilot house has been destroyed, it also gives a cover to the necessary switching mechanisms for the supply of current to the interior-communication systems. From the captain's battle station, which has been already briefly alluded to, an armored tube three feet in diameter is fitted, ending in the central station. This tube protects the steering-gear leads as well as the important wires and cables of the essentially battle and navigating circuits. In this room will be found the steering wheel, engine mechanical telegraphs, revolution indicators, helm angle indicator, electric steering telegraph, voice-tube panel, cut-out switchboard, in-

terior-communication switchboard (controlling the supply of all circuits for these systems), telephone switchboard, telephone transfer switchboard, general-alarm gong contact maker and warning-signal contact maker. Two dynamotors for the energy necessary for the general systems of interior communication are a part of this equipment, but, due to their noisy character, are debarred from the silent communion with their fellows. This control station is lined on all sides with sound-proofing material, that there may be no interruptions to the service occasioned by the ship machinery. The motor generators for the supply of proper voltages, with alternating and direct current to the telephone system, are located without the central station for the same reasons. The dynamotors for the general communicating circuits are wound to transform the standard voltage of 125 volts into three voltages, 6.6, 13.3 and 19.9 volts. Motor generators in duplicate for the telephone system consist of a motor wound for 125 volts; a direct-current generator transforming to a normal voltage of 16 with rheostatic control from 12 to 20 volts, mounted on the same shaft, and an alternating-current generator producing 80 volts at 16 cycles, mounted on the same bed plate. These motor generators are controlled by the telephone transfer switchboard, and the dynamotors are controlled by the interior-communication switchboard. This latter switchboard is interesting for the amount of control it provides crowded in so small an area. It is furnished with many sets of bus bars to accommodate the differences in potential characteristics of the various systems. It supplies 125, 6.6, 13.3, 19.9-volt bus-bars, as well as a special set of bus-bars for the batteries, which are connected to supply 6.6, 13.3 and 19.9 volts. Adjacent to the central station and made sound proof in like manner are found the substations for fire control. The two substations permit of duplicate operation of the fire control, that is to say, that the control of all the turret guns can be accomplished from one substation or divided between them. Substations are provided to agree with the number of batteries. A change is now contemplated in this arrangement of compartments

whereby there will be secured a further structural division, allowing a special compartment to interior-communication apparatus. This arrangement will separate and make distinct the steering compartment, the communicating or central station and that reserved especially for the control of the gunfire.

Although briefly described, the extensiveness of these systems goes far to prove their importance and necessity. Embracing, as they do, every possible need of the navigator, the engineer, the gunner, the passenger and the crew, they metaphorically typify the human nervous system, with all its sensitiveness and delicacy. As the human is debilitated by some injury or shock to his nerves, in like manner does the vessel suffer from an interruption to its interior signals. Following this simile to even a greater degree, man has ingeniously provided the vessel with means of premonition like unto the intuition or fear of approaching danger which man himself possesses. These advantages have transpired through man's experience, study and persevering interest in the making of vessels secure in the carriage of human life and cargo. Not one iota should be spared from the praise of man's achievement as shown in the advantages to the English-speaking races of the two transatlantic fast-mail steamers *Lusitania* and *Mauretania*. In diminishing the time of travel between our shores and that of the Fatherland they have advanced the nadir of world civilization.

No attempt has been made to discuss in this paper any practice other than that of our own country. A comparison of the practice of other nations would be interesting, but would extend beyond the prescribed intention of this treatment. It is obvious to those who are well acquainted with American characteristics that in all paths that lead to progress and advancement in science, art and civilization our countrymen will be found in the vanguard.

TEST OF TERRY STEAM TURBINE.

By Commander C. W. Dyson, U. S. Navy.

The Terry steam turbine which is being developed for naval use in driving dynamos and blowers was tested on June 15, 1909, at the works of the Terry Turbine Co., Hartford, Conn.

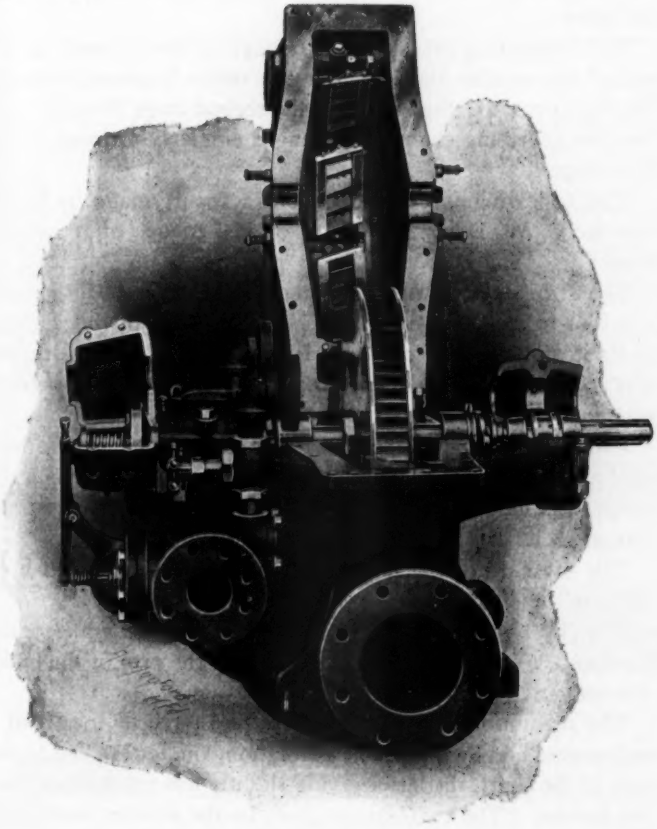
The Terry turbine is of the compound-velocity, stage, impulse type; that is, the steam is practically wholly expanded in a nozzle, wherein its static pressure is converted into velocity energy. The method of applying this energy of the steam to the turbine rotor is as follows: The wheel is fitted with semicircular buckets, as shown in figure. The steam escaping from the jet strikes one side of the bucket and is reversed in direction, leaving the opposite side of the same bucket, then enters the first stationary bucket or reversing chamber. This chamber redirects the steam back again into another bucket on the same wheel at a point adjacent to the jet. This operation is repeated as many times as necessary for the complete utilization of all the available energy in the steam, its velocity being extracted successively in each reversal or stage. The steam in acting on the buckets thus takes a spiral motion from the nozzle till it reaches the exhaust passage.

In order to allow the dead steam which may collect at the central part of the bucket to be drawn off, a small hole is made near the center of the buckets in reversing chamber. This allows any dead steam that has spent its force to be drawn off into the exhaust space.

The flow of steam into and from the buckets is at all times in a plane normal to the shaft, and there is thus no end thrust, regardless of initial pressure or vacuum.

Increased power for a wheel of a given diameter is obtained by fitting additional jets and reversing chambers in the casing,

each jet, of course, being supplied with live steam. When partial load is to be carried at times, one or more of these jets may be turned off by hand-operated valves to give full load efficiency.



TERRY STEAM TURBINE.

It is thus seen that it is the purpose to secure the advantages of increased economy of the multiple-wheel turbine with the obvious advantages of the single-wheel turbine. As the steam is fully expanded in the nozzle, the turbine casing and wheel

are not subjected to high pressures or to superheat, but only to the pressure corresponding to the exhaust pressure.

The governor is of the fly-ball type, mounted directly on the turbine shaft, and controls a specially-constructed miter throttle valve.

For condensing service the two-stage turbine is used for all except the smaller sizes. After the steam is passed through the high-pressure stage it enters the second stage through nozzles and reversing chambers arranged similarly to those in the first stage.

The following is extracted from a report made by Commander C. W. Dyson, U. S. N., on test of one of these turbines:

The turbine tested was one of their standard sizes, fitted with a 2-foot rotor. The usual number of nozzles in this turbine is eight, but for the trial only four were used. The turbine was connected to a small surface condenser in which the steam was condensed.

From the condenser the water was drawn off into two barrels, alternately, which were placed on scales and in which the water was carefully weighed, care being taken to check the tare of each barrel before each filling and weighing.

The pressure of exhaust in the turbine was regulated by a valve in the exhaust line.

The power was measured by means of a water brake, using a 5-foot arm, and the pressure exerted by the arm of the brake was measured by means of a platform scale.

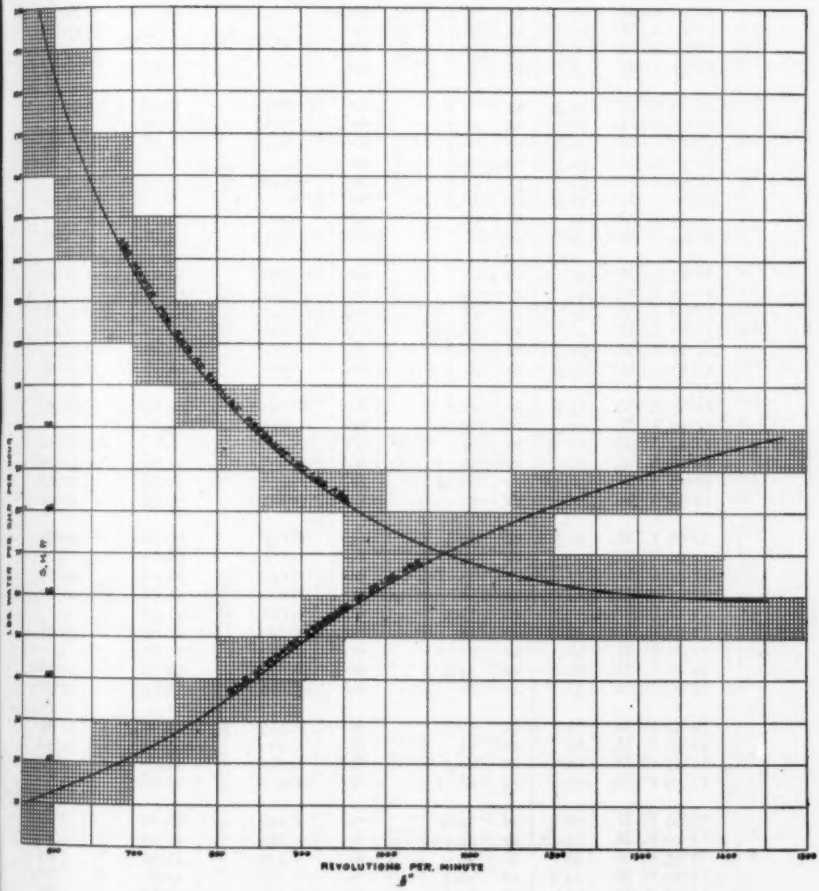
The revolutions of the shaft were registered by means of a tachometer and by a portable revolution counter applied to the axis of the shaft, the latter giving slightly less revolutions than the former. The revolutions given by the counter have been used in figuring out the powers developed.

The tests were begun at 10.20 A. M., and continued until 1.50 P. M.

Tests No. 1 were made against a back pressure of 5 pounds per gauge and an initial pressure of about 160 pounds per

gauge, this condition giving about the thermal head to be expected on the destroyers in actual service conditions.

A series of four tests with 5 pounds per gauge back pressure were run in order to give sufficient points to plot a curve of



results. The revolutions during these four tests varied from about 600 to 1,400 per minute, and the powers developed from about 6 S.H.P. to 50 S.H.P.

No. of test.	Time.	Brake, pounds.	Tare.	Net brake.		Brake arm.	Revolutions.		S.H.P.		Steam Time.
1	10·20 A. M.	58	22	36		60 in.					10·20
	10·24 A. M.	60.5	22	38.5		60	1,350		47.15		10·25
	10·28 A. M.	59	22	37	36.6875	60					10·30
	10·37 A. M.	53	22	31		60					10·35
2	10·50 A. M.	32.5	22	10.5		60	600		6.00		10·50
	10·52 A. M.	32.5	22	10.5		60	578		5.78		...
	10·54 A. M.	32.5	22	10.5		60	590		5.90		10·55
	10·56 A. M.	32.5	22	10.5		60	...		...		...
	10·58 A. M.	32.5	22	10.5	10.417	60	590	589.4	5.90	5.82	...
	11·00 A. M.	32.5	22	10.5		60	...		...		11·00
	11·03 A. M.	32	22	10		60	600		5.71		...
	11·05 A. M.	32	22	10		60	576		5.48		11·05
3	11·13 A. M.	43	22	21		60	820		19.93		11·13
	11·15 A. M.	44	22	22		60	820		17.17		...
	11·19 A. M.	43	22	21		60	744		14.87		11·18
	11·22 A. M.	42.5	22	20.5		60	800		15.60		11·23
	11·24 A. M.	42.5	22	20.5		60	820		16.00		...
	11·27 A. M.	43.5	22	21.5		60	800		16.37		11·28
4	11·37 A. M.	53.5	22	31.5		60	1,020		30.59		11·37
	11·39 A. M.	54	22	32		60	975		29.70		...
	11·41 A. M.	54	22	32		60	...		...		11·42
	11·46 A. M.	54	22	32		60	1,010		30.77		11·47
	11·50 A. M.	54.25	22	32.25	32.08	60	979	983.75	30.06	30.32	11·52
	11·54 A. M.	55	22	33		60	983		30.88		11·57
5	12·06 P. M.	57.5	22	35.5		60	1,177		39.78		12·06
	12·09 P. M.	57	22	35		60	1,161		38.68		...
	12·12 P. M.	57	22	35		60	1,141		38.02		12·11
	12·16 P. M.	53	22	31		60	1,100		32.46		12·16
	12·18 P. M.	55.5	22	33.5		60	1,176		37.50		...
	12·22 P. M.	56	22	34		60	1,170		37.87		12·21
	12·24 P. M.	56	22	34		60	1,170		37.87		...
	12·26 P. M.	56.5	22	34.5		60	1,161		38.13		12·26
	12·28 P. M.	57	22	35		60	1,159		38.62		12·30
6	12·35 P. M.	61.5	22	39.5		60	1,383		52.01		12·35
	12·40 P. M.	63	22	41		60	1,400		54.64		12·40
	12·45 P. M.	62.5	22	40.5		60	1,361		52.47		12·45
	12·50 P. M.	62	22	40	40.5	60	1,407	1,384.125	53.58	53.37	12·50
7	1·05 P. M.	56.5	22	34.5		60	1,408		46.24		1·05
	1·10 P. M.	54.75	22	32.75		60	1,380		41.65		1·10
	1·15 P. M.	56	22	34		60	1,400		45.32		1·15
	1·20 P. M.	54.5	22	32.5		60	1,385		42.85		1·20
	1·25 P. M.	52.5	22	30.5	33.0625	60	1,409	1,392.67	40.91	43.494	1·25
8	1·32 P. M.	51.5	22	29.5		60	1,900		53.36		1·32
	1·34 P. M.	48	22	26		60	1,925		47.65		...
	1·36 P. M.	50	22	28	27.375	60	1,960	1927.5	52.25	50.23	1·37

TERRY TURBINE WORKS, HARTFORD, CONN.

pressure, per gauge.				Weight of water, pounds.						Temp. steam.	
Throttle.	Steam belt.	Exhaust.		Time.	Gross.	Tare.	Net.	Total lbs. per hour.	Lbs. per S.H.P. per hour.	Line.	Cal.
160	180	5	4.9375	10·20	...	...	...	...	59.2	388	350
166	185	5		10·26	426.5	129.5	297	2,970	59.2	396	360
151	...	5		10·32	417	138	279	2,790	59.2	395	362
140	...	4.5		10·38	398	136	262	2,620	59 2	395	347
59	64	5	5.0	10·44	...	...	...	...	191.04	358	342
...	...	...		10·50	...	...	...	...	191.04	...	...
59	64	5		10·56	244.5	135.5	109	1,090	191.04	356	341
...	...	...		...	...	...	...	...	191.04	...	...
..	...	...		...	...	...	...	...	191.04	...	...
60	66	5		11·02	250	137	113	1,130	191.04	352	341
...	...	...		...	...	...	...	...	191.04	...	...
60	...	5		11·08	244.5	135	109.5	1,095	191.04	356	342
104	...	5	5.0125	11·13	...	...	...	...	109.97	369	348?
...	...	...		...	...	...	...	...	109.97	...	...
93	105	5		11·19	316	133.5	182.5	1,825	109.97	370	350
95	106	5		11·25	311.5	136.5	175	1,750	109.97	371	349
...	...	...		...	...	...	...	...	109.97	...	...
96	107	5.1		11·31	309	133	176	1,760	109.97	370	350
135	150	5.1	5.07	11·37	...	...	...	...	83.61	390	366
...	...	...		...	...	...	...	...	83 61	...	...
140	155	5.1		11·43	383	135	248	2,480	83.61	393	368
142	158	5.1		11·49	393	136.5	256.5	2,565	83.61	396	368
145	...	5		11.55	388.5	135.5	253	2,530	83.61	402	375
140	155	5		12·01	...	...	...	...	83.61	402	376
165	186	15	14.719	12·06	...	...	...	...	77 83	412	380
...	..	...		...	...	...	...	...	77.83	...	...
162	184	15		12·12	434	136.5	297.5	2,975	77.83	412	381
150	178	14		12·18	418	136.5	281.5	2,815	77.83	414	...
...	...	...		...	...	...	...	...	77.83	...	...
170	188	15		12·24	429	134.5	294.5	2,945	77.83	416	...
...	...	...		...	...	...	...	...	77.83	...	...
168	189	15		...	...	...	...	...	77.83	412	...
164	185	14.5		12·30	433	137.5	295.5	2,955	77.83	412	376
166	185	1.2	1.35	12·35	...	...	...	...	55.91	414	...
170	189	1.4		12 41	436.5	138	298.5	2,985	55.91	416	379
168	185	1.4		12·47	438	137	301	3,010	55.91	418	383
160	185	1.2		12·53	428 5	135.5	293	2,930	55.91	416	..
135	145	14.0 in. vac.	~6.97 lbs.	1·05	...	...	...	...	55.93	414	...
136	150	14		1·11	377	135	242	2,420	55.93	412	388
140	155	13.5		1·17	385	138	247	2,470	55.93	414	...
128	140	13.9		1·23	373	136	237	2,370	55.93	412	...
126	140	13.9		1·29	...	...	...	...	55.93	410	387
122	139	14	~6.875	1·32	...	...	...	...	44.49	408	...
...	...	...		1·38	360	136.5	223.5	2,235	44.49	...	...
132	145	13.5		1·44	...	...	...	...	44.49	408	...

Gauge incorrect.

Test No. 5 was at about 1,200 revolutions and against 15 pounds per gauge back pressure.

Test No. 6 at about 1,400 revolutions and 1.35 pounds per gauge back pressure.

Test No. 7 at about 1,400 revolutions and 15 inches vacuum.

Test No. 8 at about 1,930 revolutions and 15 inches vacuum.

During all the tests except the last the turbine ran smoothly, noiselessly and without vibration. During the last test, which was made simply from curiosity, there was considerable vibration and the whirring of the turbine could be distinctly heard.

The results of the trials are shown in the accompanying table, and those of the first four tests by the accompanying curve.

In case a fan can be obtained to hold a fair efficiency at about 1,400 revolutions, it appears, from the above tests, that the Terry turbine will be satisfactory as a motor for forced-draft purposes. Even if the cost in steam for equal results should slightly exceed that of reciprocating engines for the same purposes, the greater reliability of the turbine would seem to justify this extra cost, as the majority of the troubles experienced on destroyers and torpedo boats are from the blower reciprocating engines.

It may be mentioned that the speeds run on this test are considerably lower than when the turbine is used for other services. The standard speed for the machine is 2,500 r.p.m., and at this speed the economy is considerably better than at the speeds turbine was run in these tests.

Terry turbines are being used in the naval service for dynamo drive on battleships and for the forced-draft blowers of some of the late destroyers.

A TEST OF THE IMPROVED REYNOLDS DENSE-AIR ICE MACHINE, WITH OBSERVATIONS ON REFRIGERATION ON BOARD NAVAL VESSELS.

By Commander Wm. Strother Smith, U. S. N.

In order to assure themselves that the improved design of the Reynolds Dense-Air Ice Machine would prove wholly efficient, or if not, to find out just what was needed to perfect this machine, the builders, the W. D. Forbes Co., of New London, Conn., conducted a test of sufficient length of time to develop faults if any were to be found.

Through the courtesy of Mr. Forbes, arrangements were made so that the writer was enabled to be present at practically all times during the entire time of ninety hours.

The machine was erected on wooden skids in the machine shop, but not secured to the floor. Just outside of the shop a cold-storage house was built, divided into two rooms, each supplied with cold air direct after the supply had first passed through the ice-making box. The return joined in a common pipe to the machine or recooler.

Figure I shows the machine, running, before the pipes were lagged. The ice-making box is just behind the machine, near the windows. The cold-storage rooms are just outside the supply and return pipes passing through the windows.

Fig. II shows the plan, elevation and end view of the cold rooms. The walls of these rooms were built of two thicknesses of one-inch spruce boards spaced six inches apart, heavy lagging under the inner skin and the six-inch space filled with sawdust.

The capacity of each room is 1,000 cubic feet, the area of wall surface 636 square feet, and the area of piping for cold air 238 square feet. The piping was arranged in two coils

in each room, the supply entering the top coil at the bottom and the lower coil at the top.

Fig. III shows a longitudinal section through the compressor and steam cylinder. The air enters at A from the discharge of the primer pump and passes through the film space separator, the inner wall being cooled by water circulation, and the moisture is here collected and blown off. The air then passes to the under side of the compressor slide valve. This valve is actuated by a rock shaft. Beside the piston rod this rock shaft is the only rod to be packed.

The primer-pump separator is one of the features of this machine.

Fig. IV shows an end view. The compressor cylinder is on the right hand, with the primer pump outside. The discharge pipe from the primer pump enters the separator at A. The recooler is shown partly in section.

Figs. V and VI are cards taken simultaneously from the compressor and expander cylinders. The compressor pressure was 282 and the expander 61.

Before starting the test the machine was disassembled for examination.

The test was started at 10.30 A. M. on May 21st. The ice-making tank contained nine cans of water of 14 pounds each, and at a temperature of 112 degrees Fahrenheit. The cold-storage rooms were at a temperature of 56 degrees Fahrenheit, the outside air 59 degrees Fahrenheit, and the circulating water 55 degrees Fahrenheit.

In one hour and twenty-five minutes the normal running pressures of 285 pounds and 60 pounds per gauge on the compressor and expander cylinders was reached. In two hours the water in the cans had been cooled to 43 degrees Fahrenheit; in three hours ice formed in all cans, and in six hours all cans, including the surrounding solution of calcium chloride, were solidly frozen. At no time were the cans shifted so that those entirely frozen were replaced by the one farther away from the entering cold air. This would have reduced the freezing time in all cases.

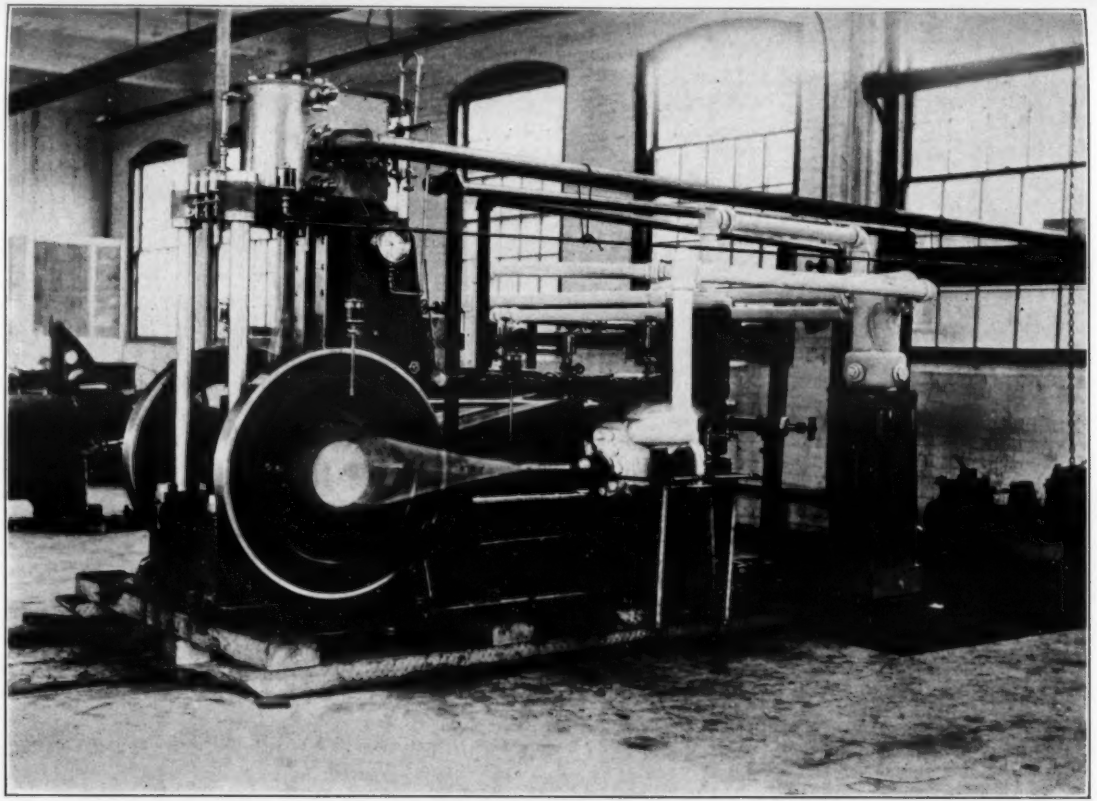
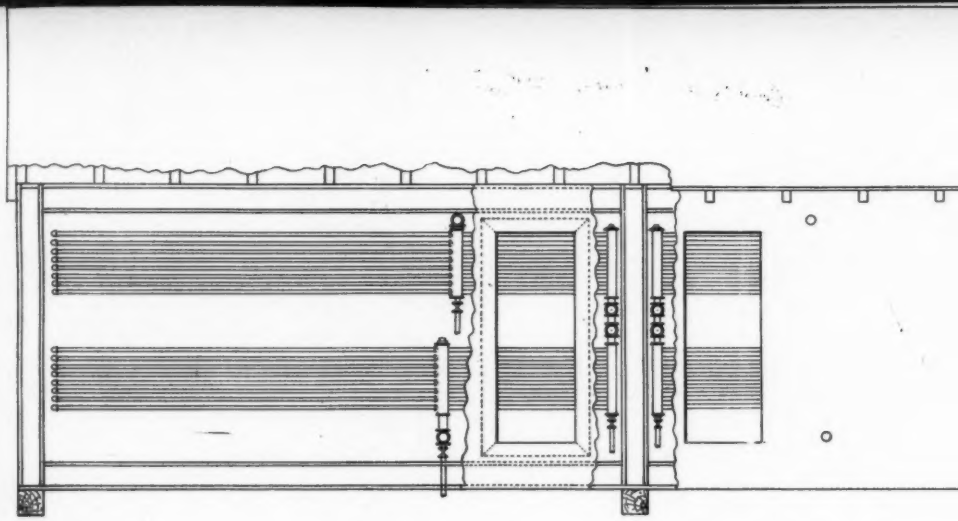
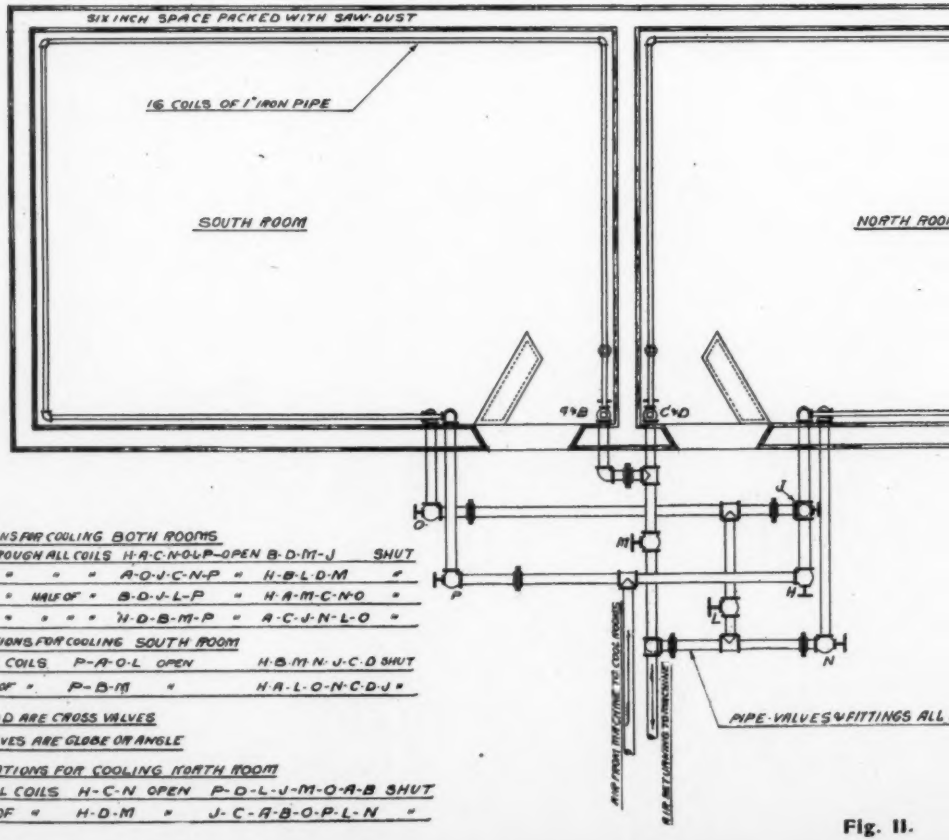


Fig. I.





COMBINATIONS FOR COOLING BOTH ROOMS

AIR IN PARALLEL THROUGH ALL COILS	H-A-C-N-O-L-P	OPEN	B-D-M-J	SHUT
" " SERIES	" " "	A-O-J-C-N-P	"	H-B-L-D-M "
" " " " HALF OF "		B-D-J-L-P	"	H-A-M-C-N-O "
" " PARALLEL " " " "		H-D-B-M-P	"	A-C-J-N-L-O "

COMBINATIONS FOR COOLING SOUTH ROOM

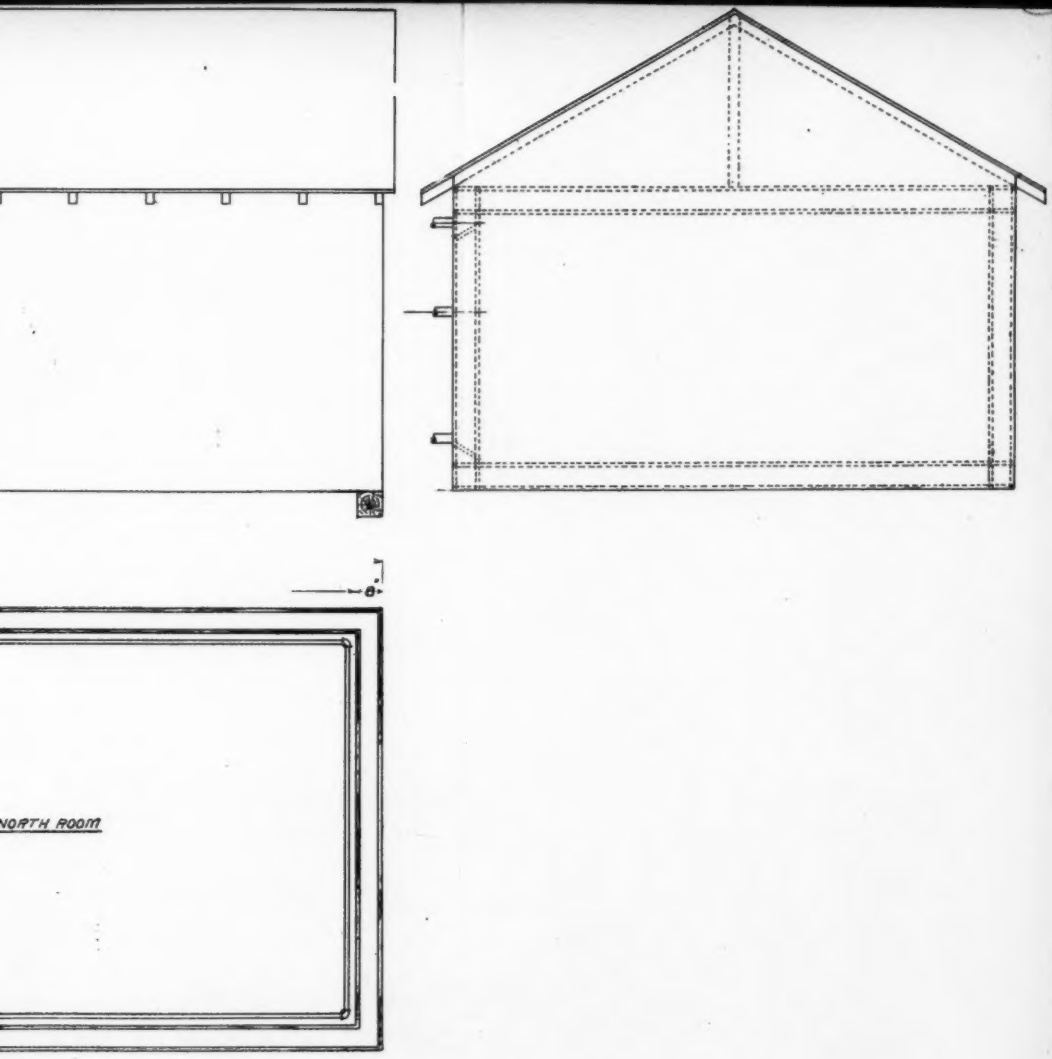
AIR THROUGH ALL COILS	P-A-O-L	OPEN	H-B-M-N-J-C-D SHUT
" " HALF OF "	P-B-M	"	H-A-L-O-N-C-D-J "

NOTE! B & D ARE CROSS VALVES
OTHER VALVES ARE GLOBE OR ANGLE

COMBINATIONS FOR COOLING NORTH ROOM

AIR THROUGH ALL COILS	H-C-N	OPEN	P-O-L-J-M-O-A-B SHUT
" " HALF OF "	H-O-M	"	J-C-A-B-O-P-L-N "

Fig. II.



PROPOSED ARRANGEMENT OF COOL ROOMS
SCALE 1/2" = 1' DRAWN BY G. Young FEB. 8 1909

TTINGS ALL 2½"

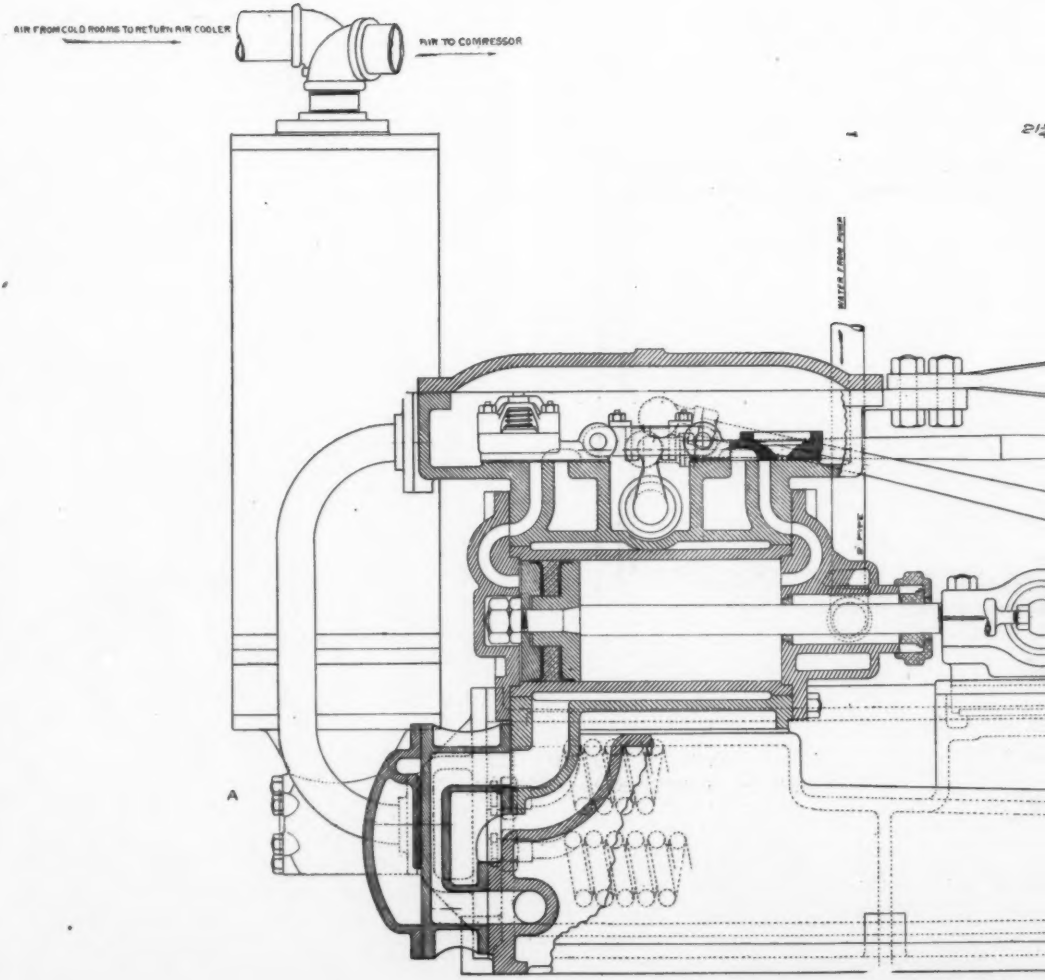
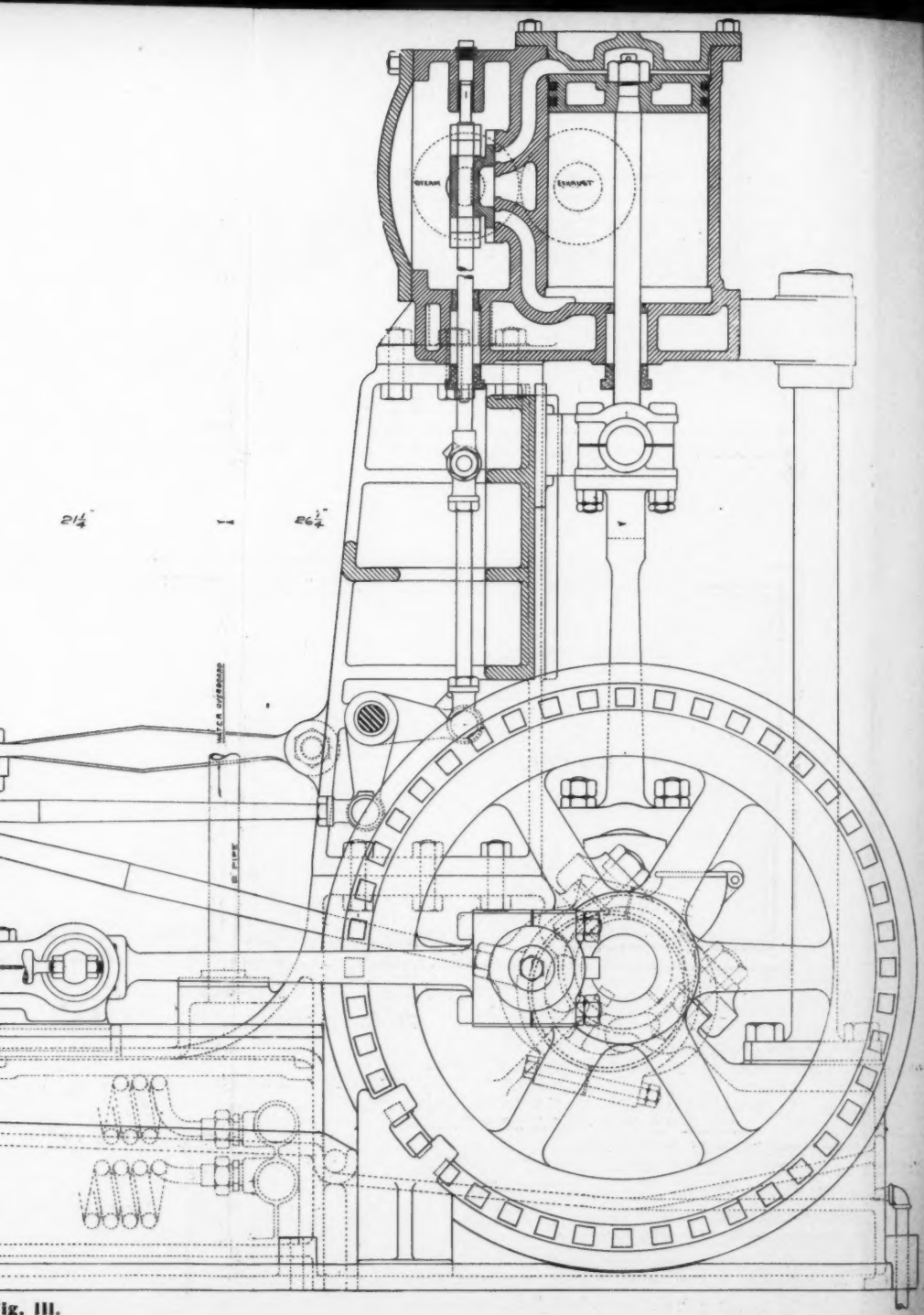
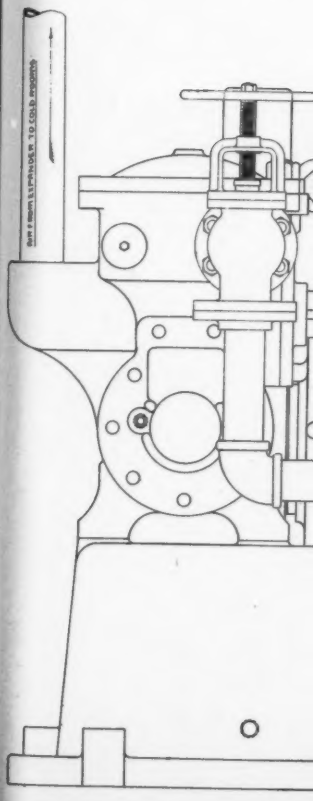


Fig. III.



ig. III.

AIR FROM COLD ROOMS TO RETURN AIR COOLER



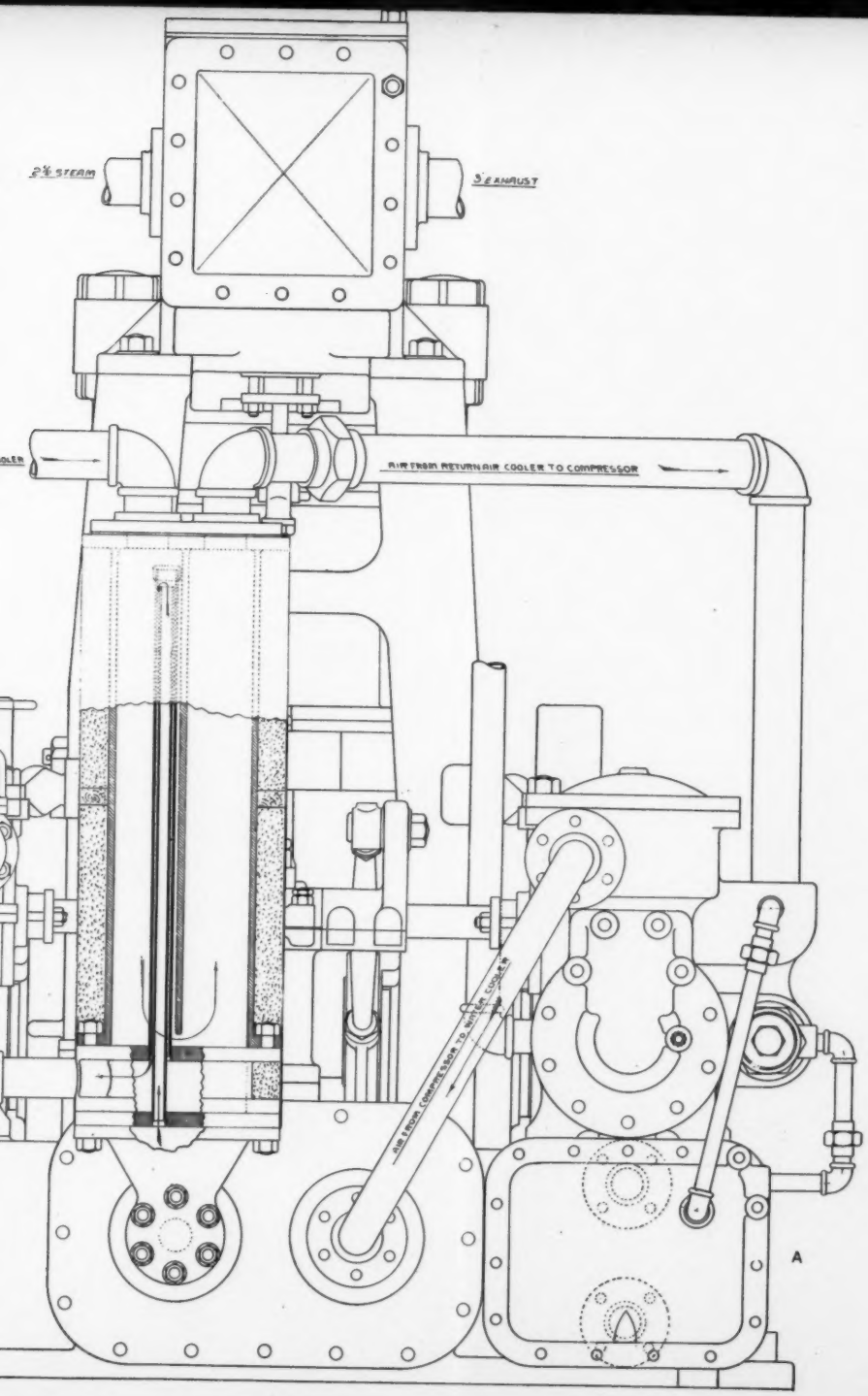
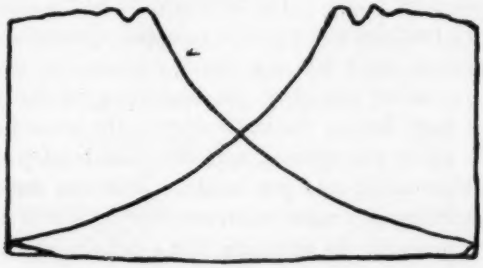

2½ STEAM
EXHAUST
AIR FROM RETURN AIR COOLER TO COMPRESSOR
AIR FROM COMPRESSOR TO WATER COOLER
A

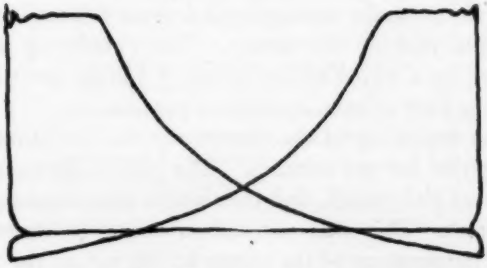
Fig. IV.

In view of the difficulty of removing the cans, owing to a poor solution in the freezing box, the ice box was cut out after eight hours and kept out until the end of the first twenty-four hours, when a fresh supply of calcium chloride was provided.

In fourteen and a-half hours from starting the cold-storage rooms registered zero degrees, the returning air to the machine being plus 5 degrees. At the end of the first day the cold storage reached minus 13 degrees Fahrenheit and the returning cold air minus 9 degrees Fahrenheit.



M.E.P. = 93.5. **Fig. V.**—COMPRESSOR. Scale of spring, 150.



M.E.P. = 70.5. **Fig. VI.**—EXPANDER. Scale of spring, 150.

The temperature of the cold air leaving the expander cylinder dropped from minus 38 degrees Fahrenheit at the end of the first hour to minus 56 degrees Fahrenheit at the end of the twenty-fourth hour. The machine averaged 107 revolutions.

The first day's running served to try out the running of the machine, but gave little or no idea of its efficiency under service conditions.

At the beginning of the second day the real test began by heating the circulating water to about the hottest met with in tropical waters. The temperature of 85 degrees Fahrenheit was selected, and by means of a steam water heater a fairly constant supply was maintained, varying from 82 degrees to 88 degrees Fahrenheit, and averaging 85.2 degrees Fahrenheit for twenty-four hours. The temeprature of the cooling water leaving the machine averaged 92.5 degrees Fahrenheit.

The second day's run was made without the use of a recooler, this being cut in at the beginning of the third day.

A half hour before the beginning of the second day's test, the south room was opened, and 280 pounds of water at 125 degrees Fahrenheit was put inside. This was done to simulate the opening of a meat room and storing warm meat.

This is probably the first time that a definite idea is obtained of the relative value of a recooler fitted to a dense-air machine. It will be seen below that, with practically all other conditions being just about the same, the gain in temperature of the air leaving the expander averaged 7.8 degrees Fahrenheit the third day below that of the second. The circulating water was measured by a tested meter, being 97 gallons per minute, the flow being kept as near constant as possible.

At the beginning of the fourth day the cold-storage rooms were opened for ten minutes. The outside temperature was 77 degrees Fahrenheit, and the thermometer showed a rise of 14 degrees. This was reduced to within 3 degrees of the former temperature of the rooms by the end of the first hour.

The last day's run was under the same conditions as the previous day, and give practically the same results.

Below, in tabulated form, are given the average observations for the second and third days. The last sixteen hours of each day are taken so as to indicate the action after a uniform state was reached under changed conditions.

While reporting upon the test of this particular machine the

following observations of refrigerating plants in general may explain why the machine is often blamed when the fault may lie in many other parts of the installation. Air leaks in the machine or any part of the circuit of piping, due to leaks around packing, leaking joints, or badly fitted cup leathers, are looked for first of all. The efficiency of the plant depends a great deal upon the arrangement of the piping in the cold-storage rooms. The cold air should always enter at the top of the coils and leave at the bottom. An easy circulation must be provided by having the area of the first pass slightly larger than the supply pipe, the second pass still larger, and the third and discharge should be still further increased. This will lessen the work on the expander cylinder.

Observations recorded.	Second day.	Third day.
Revolutions per minute	107	109
Steam pressure, pounds	45.8	48.0
Compressor pressure, pounds	284.0	282.0
Expander pressure, pounds	59.0	61.0
Temperature of circulating water, degrees F	85.2	85.0
discharge water, degrees F	92.5	94.5
machine room, degrees F	63.0	70.0
outside air, degrees F	50.0	53.0
air from expander, degrees F	−33.7	−41.5
return air to expander, recooler in use, degrees F	...	71.2
return air to expander, recooler not in use, degrees F	92.8	...
return air to expander, degrees F	22.4	19.9
compressor, degrees F	28.2	49.2
cold room A, degrees F	18.3	14.4
cold room B, degrees F	14.9	12.2
Average time for freezing a batch of ice, hrs. and min.	3–29	3–28
Weight of each freeze, pounds	126	126

Arrange the cold-storage piping so that it may be thoroughly drained and blown through. Very often a marked improvement will be found in a cold room by removing all stores from the room at every opportunity and blowing through with hot air. Since it is impossible to run a dense-air machine without oil in the cylinders, some will reach the piping and reduce its conductivity. To remedy this as much as possible, the following has suggested itself: Arrange all the piping in cold

room in a series of coils similar to heating coils supplied from a manifold pipe as high up on the sides as possible and discharging to a manifold at the bottom. These coils may be made of one piece, and so arranged that they may be cut off, taken down and out of the room for thorough cleaning.

This arrangement will probably reduce the number of joints below that now usually fitted. The latest arrangement of cold-storage rooms is that fitted on the *Delaware* and shown in Fig.

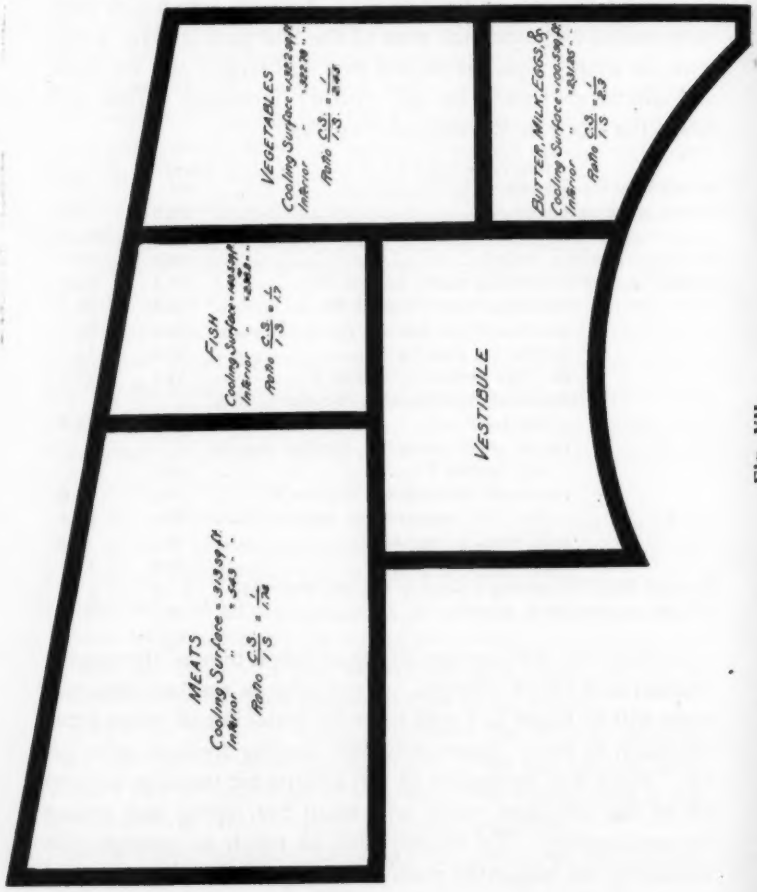


Fig. VII.

VII. In this the piping in the rooms has been proportioned so as to give the best results in tropical waters. The proportions are shown in the figure. It has been aimed to keep the meat room at from 25 degrees to 30 degrees Fahrenheit; the fish room at 20 degrees to 25 degrees, the butter and egg room at 34 degrees to 40 degrees, and the vegetables at 35 to 45 degrees.

In cruising with a circulating water of 70 degrees and under, one machine should be all that is necessary for all purposes, but there should be no difficulty in maintaining the above at any time with both machines.

To examine the test room used it will be seen that the conditions were not at all favorable. The proportion of cooling to wall surface is about 1 to 2.67, and the air enters the top cooling coil at the bottom.

The tested machine has, at this time, been about two months in use on board the S. S. *Iroquois,* and has been reported as giving excellent results.

Fig. VII.

UPKEEP OF THE PARSONS MARINE STEAM TURBINES OF THE U. S. S. *CHESTER*.

By Lieutenant A. F. H. Yates, U. S. Navy.

Early in July of the present year the U. S. S. *Chester* arrived at the Navy Yard, New York, having completed fourteen months of her first commission, during which time she had steamed slightly over thirty-three thousand and five hundred miles. No repairs to her turbines had been effected during this period, and, with the exception of several points to be remarked upon, the machinery and boilers were in excellent condition. Several items were considered worthy of attention at this time, however, and a three-weeks' stay at the Navy Yard afforded an opportunity. The item of turbine work considered most necessary was, "fit new stems on all turbine micrometers, the present stems were too much worn for reliable results." In addition the following two items were considered necessary:

"Open and examine the starboard low-pressure turbine casing for examination of the astern turbine."

"Open and examine high-pressure cruising turbine, re-align its shaft, and repack its steam glands to suit the re-alignment."

It was also proposed to make the usual routine examination of bearings, oil service, etc.

The item first mentioned was occasioned by the wear on the end of the micrometer stems due to long and frequent usage. The construction of the micrometers is such that considerable wear can be experienced before it is necessary to fit new stems. They are made of Tobin bronze, and their ends bear lightly on the faces of the dummy pistons as the turbine revolves, at such times as readings are being taken for the determination of the

dummy clearance. Their manufacture is not difficult, and where it is only necessary to replace one or two the work is easily within the capacity of the ship's force. The second item referred to was considered necessary because of a falling off in the efficiency of the starboard astern turbine. Before the examination was made, however, it was considered very doubtful whether or not this was due to internal derangement. The history of the case is considered of sufficient interest to relate in full, as the conditions found to exist in this turbine after it was opened were surprising. A considerable portion of the blading was either stripped or badly deformed, though a complete examination could not be made owing to unexpected orders for the ship to proceed to sea, necessitating the assembling of the turbine without repairs. Throughout the greater part of the time the vessel had been in commission this particular astern turbine had not started with the same ease as the port astern turbine on occasions when the turbines were being tried preparatory to reporting them ready for getting underway. Its behavior on such occasions had been erratic and followed no definite rule, though repeated trials of the same turbine appeared to show it to run normally, and it had never failed on the very great number of occasions when its operation was required in getting underway and coming to anchor. Considerable wonder was felt because of its peculiarity, but it was concluded that the cause for it was abnormal swelling of the lignum vitae in the outer bearing of the shaft. Especial attention was always paid to watching its operation, and it was always carefully observed whenever getting underway and coming to anchor. It is not ordinarily practicable to determine the number of revolutions per minute made by the astern turbines, as backing signals do not remain in force for long intervals, and for this reason no accurate comparison of this turbine with its mate can be made. It was usually possible to form a fairly close comparison by observing the relative speeds of the governors on the two inboard shafts which carry these turbines. I had always felt that the starboard astern turbine backed slightly slower than the port one, but the difference was

never considered serious. It was not until the end of May, 1909, that this turbine was found to fall materially below its normal speed. This was on the occasion of leaving an African port, preliminary to the return of the vessel to the United States. For the moment I was alarmed, but, in view of certain conditions and developments, I still had insufficient reasons for considering the cause to be due to internal derangement.

The ship's bottom had become extremely foul, following a long spell at anchor at Monrovia, Liberia. Then, again, upon the arrival of the ship at Dakar, Senegal, divers who cleaned the propellers of marine growth reported all propeller blades to be bent. It was only after docking at the New York Navy Yard that the real condition of the propeller blades could be ascertained. They were not badly bent, but those of number two shaft, carrying the starboard astern turbine, were slightly worse than the others. It still looked as though there might be no necessity for opening up this turbine for examination, but in order to make certain, the work was undertaken. The casing was lifted and the upper half of the casing and the spindle blading were open to inspection. On each of these parts nearly all blades of the first stage were stripped except in the first row. Similarly the first three rows of blades of the second stage were deformed so badly as to almost entirely blank off the passage of steam through them. In the third stage of blading a few blades were slightly damaged on their tips and some of the lacing strips cracked. On each part the first row of the first stage was nearly intact. One blade was missing from the first row of the first stage of casing blading, and but a few were missing from the first row of spindle blading. The remarkable point about the matter is the fact that, in spite of this damage, this turbine preserved as high an efficiency as it did. This appears more remarkable as one examines the first three rows of blading in the second stage and sees how completely they were blanked off to the admission of steam. When using 125 pounds steam pressure per gauge in this turbine it should develop about 390 revolutions per minute, whereas in its damaged condition it developed about 170.

At this point it may be well to review the history of the turbine more carefully in order to discover the reason for the conditions found.

Records indicate that the turbine was in excellent condition on the occasion of leaving port (in commission) for the first time, May 18, 1908. In fact, on this occasion the machinery was given an unusually severe test, eighty-five signals being received and responded to within the first fifty minutes underway. This included two "emergency full-speed astern" signals, when more than the normal steam pressure for full-speed astern was used. During the passage made at this time a special test of the main and astern turbines was held for the determination of proper steam-belt pressures to use as standards for maneuvering at slow, half and full speeds when maneuvering in port. These observations showed the astern turbines to both be in efficient condition, and the common result obtained by averaging the two was as follows:

10 pounds pressure per gauge	142 r.p.m.
25 pounds pressure per gauge	170 r.p.m.
40 pounds pressure per gauge	222 r.p.m.
110 pounds pressure per gauge	360 r.p.m.
130 pounds pressure per gauge	400 r.p.m.

Subsequent to this time the vessel got underway and came to anchor three times with no unusual developments. On the next occasion, however, May 26, 1908, when trying the starboard astern turbine, preparatory to getting underway, it developed a shrieking noise when worked up to 18 pounds pressure. The turbine was stopped and further heated, with its throttle valve cracked to the admission of steam, and after a short interval the trial was repeated and the turbine worked well. After this occurrence this turbine was always carefully watched, but there appeared to be no reason for attaching particular importance to the event mentioned. As time went on, however, this turbine began to require a higher initial pressure than usual when trying it out for getting underway, but it appeared to run normally after being prepared for operation.

The port astern turbine usually started under 5 pounds pressure when first tried, and never required more than 15 or 20 pounds. The starboard turbine had formerly acted similarly, but later it at times required 40 or 50 pounds, and frequently 75 or 100. Then, again, it would start under lower pressures, but on one occasion, in August, it required 150 pounds. These events would tend to show that blade stripping occurred at somewhere about this time, and, while minor in extent at the start, was gradually becoming worse. With the scant clearance in this type of turbine it seems almost incredible that such an effect could be gradual, but the history of the case leaves no other conclusion. Finally, the efficiency of this turbine dropped to a point which could not well be accounted for without thorough investigation.

The most logical explanation would appear to be that the damage was caused by water, and the fact that the turbine is improperly provided with drains. Holes are drilled through the bottom of the cylinder at points between the first and the second stages and the second and third, and the small quantity of water such as might form at these points is free to drop through these holes into the drain well in the after end of the low-pressure casing. Also water is free to find its way to the exhaust end of the turbine and drop into the drain well from this point. There does not appear to be proper provision for draining the steam belt proper, and if a heavy charge of water appears therein when steam is admitted, it must of necessity be driven with the steam through the blading. The plans do not show such provision, though it is possible that when a complete examination becomes practicable a hole may be found drilled through the belt in the bottom. The usual practice with astern turbines is to fit a pipe drain between the steam belt and low-pressure drain well, always open, and this should have been done in the present case. Blading in the Parsons turbine as a rule will stand charges of water without difficulty, simply breaking it up into small particles and forming a spray with the steam; but the blades of the first stage of the astern turbines of this ship are of the weakest of all the stand-

ard sizes used, and it can readily be seen that it could not be expected to successfully stand heavy charges of water.

A close examination of the condition of the damaged blading, particularly of the first row of the first stage, shows this row to be intact except for a few blades; and indicates a strong probability that these few missing blades were the cause of the rest of the damage. I believe that this was the case. Steam admitted to the steam belt first strikes the first row of fixed blades, on the cylinder. It then strikes the first row of moving blades, on the spindle, and so on, alternately. It is believed that on some occasion when the turbine was tried a charge of water in the steam in striking this first row of fixed blades dislodged the one blade which was missing, and that this blade stripped the few that are missing in the first row of moving blades. With so many blades stripped it is easy to see how all the remaining rows of the first stage could be damaged. The blades of the second stage withstood stripping because of being of heavier material and better secured. A description of how blading is secured and of its principal dimensions should make this evident. The first stage is composed of six rows, each row being of the same height and the same pitch, height $\frac{1}{2}$ inch, pitch $1\frac{1}{8}$ inches. The second stage, also, has six rows, each of the same height and pitch, height 1 inch, pitch $1\frac{3}{8}$ inches. The third stage is composed of eighteen rows, each row of the same height, 2 inches, but it provides for three degrees of expansion, in that the first six rows are $1\frac{3}{8}$ inches pitch, the second group of six rows of $1\frac{1}{2}$ inches pitch, and the third group of six rows of $1\frac{1}{2}$ inches pitch. Upon the height and strength of the blading depends the means taken for securing it in position. Blades of all sizes are calked into the blading grooves, but, in addition to being secured in this manner at their base, those of sufficient height are bound to one another by a lacing strip, and those of still greater height are further secured by binding wire. Thus, the $1\frac{1}{2}$-inch blading which makes up the six rows of the first stage of the astern turbines is of too scant height to permit of being secured with a lacing strip, and has no support other than that

of being firmly calked into place at its base. The second-stage blades are of sufficient height to permit of the use of lacing strips, and benefit by this additional support. They are not sufficiently long to make the use of binding wire, and it is omitted. The blades of the third stage are of much greater height, and are fitted both with lacing strips and binding wire. It can thus be seen that there is a marked difference in the relative strength of the three different stages of blading, and that the blading of the first stage is much the weakest.

Upon examining the damaged parts the first impulse was to conclude that it was the result of unequal expansion, causing the spindle blades to rub against the cylinder casing. The dummy strips were found, however, to be in excellent condition, and as the clearance over their edges is less than half that over the blade tips it would hardly be expected that this could be the cause. The clearance over the edges of the dummy strips is .02 inch. The blade-tip clearances in the first stage are .045 inch, in the second stage .05 inch, and in the third stage .06 inch. An examination of the surfaces radially adjacent to the blade tips showed no indications to lead to such a belief, and this theory was abandoned, and especially in view of the fact that the turbines had on all occasions been given very careful warming up preparatory to trials.

Another idea that came up in this connection was the possibility of the damage having been due to small vibrations of very high frequency. This is supposed in some cases to cause stripping. My reason for forming this idea was based on the manner in which the cylinder casing of this turbine is supported. It lies horizontally, of course, and it is supported circumferentially by bolts at one end only. There is little chance of this having been the cause, as vibration is almost entirely absent in all of the turbines, and its occurrence at any time is rare and very slight.

Everything tends to indicate that the difficulty is of long standing, and, such being the case, this turbine has a remarkable record in successfully standing up under the severe tests that have been imposed upon the machinery.

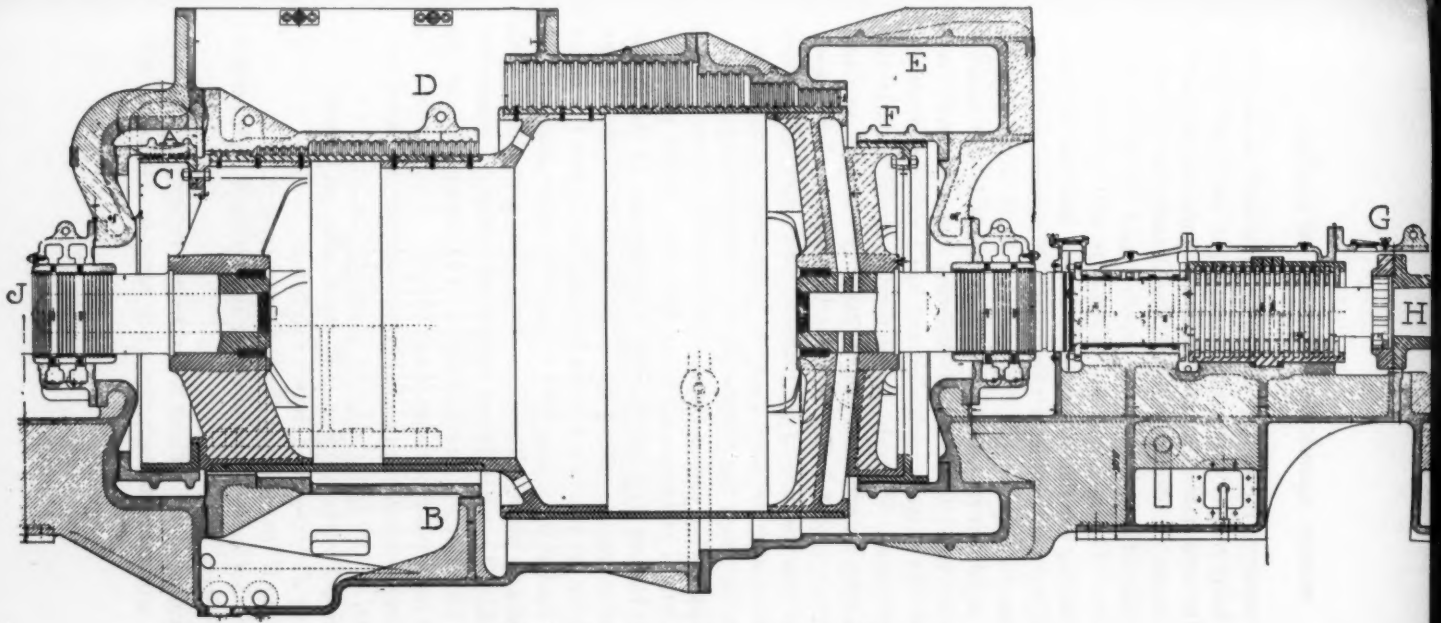


Fig. 1.—Low Pressure and Astern Turbine.

A. Astern steam belt.
B. Drain well.
C. Dummy (radial type).
D. Exhaust for L.P. and astern turbine.
E. L.P. steam belt.
F. Dummy (contact type).
G. Expansion coupling between I.P.C. and P.L.P.
H. I.P.C. Shaft.
J. Gland.

The repair of the damage cannot be considered an extensive job, it being mainly dependent upon proper facilities and material for undertaking it, as well as workmen accustomed to turbine work. Indeed, the repairs could easily be undertaken by the ship's force, if properly supplied, and within a reasonable time. The fact that the vessel was able to leave port before having the damage repaired should convince the skeptical of the extraordinary vitality which turbine machinery possesses.

The repair work necessary consists solely in the removal of the damaged blading and replacing the same with new blading. The damaged blades and their calking pieces are easily removed. Lengths of blading material of standard sizes being procured should be cut to proper lengths, saw-cuts made where required (for lacing strips), and calking grooves stamped into the base of the blades. This should all be done at one time with the same machine. The latest forms of blading also have their tips champered down to a thin edge. Calking strips having curves corresponding to the blades are also cut to length from standard-size material. These pieces fit into the blading grooves alternately at the base of the blades. The blades and the calking strips are alternately tightened into the groove by means of a calking tool, and after the entire row is bladed the lacing strip is inserted in the saw-cuts and soldered into place. Then, too, the binding wire, when used, is fitted. The latter is not considered necessary unless the blades exceed 1¾ inches in height. The composition of the various materials mentioned is as follows:

Blading.—Special-drawn hard brass—copper, 72 parts; zinc, 28 parts.

Calking Strips.—Copper, 63.5 parts; zinc, 36.5 parts.

Lacing Strips.—Solid-drawn soft brass.

Binding Wire.—No. 21 B. W. G. copper wire.

Silver Solder.—A special solder containing a high percentage of silver.

Reblading is not difficult and does not require an especially skilled workman, though the work must be conducted with

care. The most delicate part of the work consists in soldering the lacing strip in position, where it passes through the saw-cuts in the blades. A special blow-torch must be used for the purpose, capable of developing a very small flame of intense heat. The flame used should be about the size of the lead in a pencil, and care should be exercised in not allowing it to strike the surface into which the blades are anchored. The work could all be undertaken on board the ship, by lifting the upper half of the casing clear and placing it to one side, then lifting the spindle well up in the air clear of the lower half of the casing. Three squads could then proceed with the work at the same time. Upon completing a job of this nature steps should be taken to determine the blade-tip clearances which result. This is done by placing leads around each row of

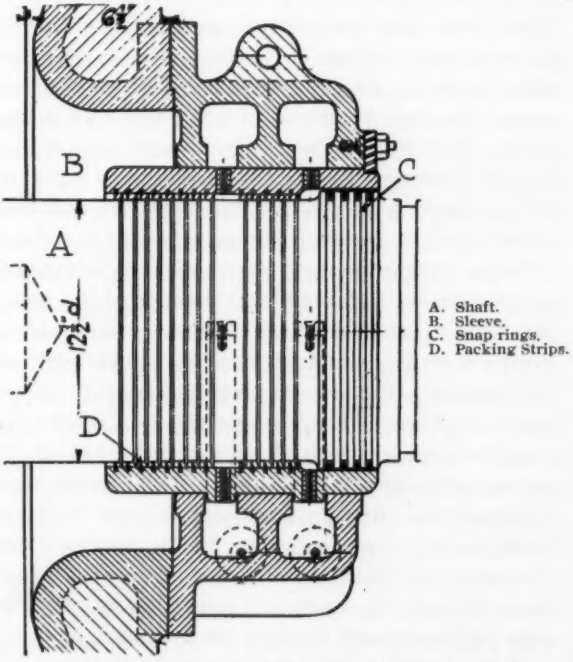


Fig. 11.—STEAM GLAND.

blades in the turbine and re-assembling it. Then, upon re-opening it, an examination of the leads tells the story, and high spots on the blading can be filed off, and the operation repeated if necessary. It is most important that the clearances be satisfactory before finally assembling the turbine.

The work on the high-pressure cruising turbine consists principally in securing a re-alignment of the shafting and making its steam glands tight. Figure II shows the construction of the steam gland. The gland is made up of an outer casing and an inner sleeve. Rows of brass strips are calked into the sleeves and alternate rows are calked into the shaft. These strips are champered down to a thin edge which just clears the surface radially adjacent. Snap rings of composition H are fitted in the shaft at the outer end of each gland sleeve as a further means of making the gland tight. These snap rings are whole rings opened sufficiently to permit of their being snapped into their grooves after being passed over the shaft. In some later installations where rings are of larger size they are made in two parts with a loose dovetail joint. In some of the earlier installations snap rings were used exclusively to make the gland steam tight, but as these did not prove a success packing strips are now fitted as mentioned above to make up the inner part of the gland.

When the turbines of this vessel were installed the packing strips were cut to leave a tip clearance of .01 inch, that being the practice at that time. Recent practice, however, is to finish the strips to an exact wearing contact, with no clearance whatsoever. The steam pockets inside of all snap rings, shown in Figure II, are connected by a branch pipe with an equalizer pipe to which all similar pockets of all other turbine glands are connected. Leak-off steam passes into the gland equalizer pipe through these branch pipes in the case of turbines having steam leakage. In the case of those in which the internal pressure is below that of the atmosphere and there is air leakage in, instead of steam leakage out, the equalizer pipe supplies steam through these branch pipes to the steam pockets, thereby sealing the gland to air leakage.

In the interests of economy there must be as little leakage as possible over the packing strips, though a perfect seal can hardly be expected in a gland of this nature. What steam does pass over the packing strips is expected to be held inside of the gland by the snap rings and carried away from the steam pockets to the equalizer pipe. A certain amount is sure to find its way into the atmosphere, however, as these rings must be fitted fairly loose in order that they may float freely. Practice shows that the packing strips should be kept tightly packed for best results. As the main journal bearings wear down with service, it can be seen that the edges of the packing strips will wear off and increased clearance will result over the upper part of the shaft. In the case of the high-pressure cruising turbine, now being referred to, the main journal bearings were found to be worn down about .01 inch, and as the packing strips in the steam glands of this turbine were originally fitted with just that amount of tip clearance it can readily be seen that an examination of these strips should have shown those of the shaft and the lower half of the sleeve to be slightly worn from rubbing. Such was the case, and those on the upper half of the sleeve showed no wear whatever. It will also be seen that as a result of this wear on the bearings the total clearance over the tips of the strips on the top half of the shaft would be .02 inch. With such an opening excessive leakage would result, and it was this condition which it was considered necessary to remedy. In addition it was considered advisable to take advantage of the opportunity and lift the upper casing of this turbine for a routine examination internally. There was no special reason for considering the latter necessary, though it was intended examining two small leaks in the casing joints that had been kept tight from time to time with rust cement. In this connection it may be mentioned that it is not a bad plan to examine a fair proportion of the turbines each year as a matter of routine. Time did not permit of opening the casing of this turbine, so this item was postponed, as was also the repacking of the gland. The shaft was, however, re-aligned, the spare brasses being fitted. The repacking

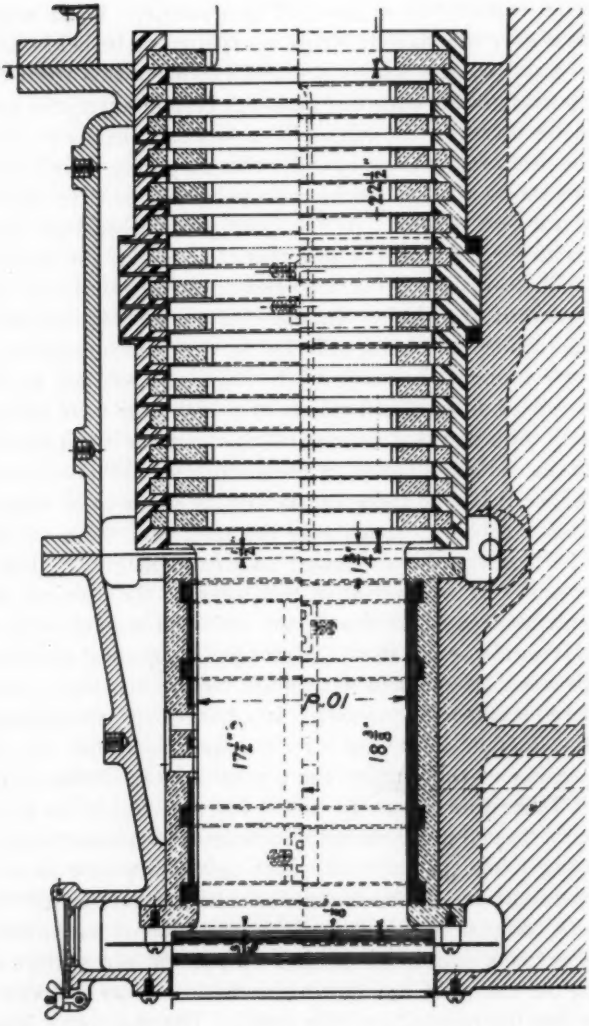


Fig. III.—Detail of Thrust and Main Bearing.

of the glands with new strips is not an extensive job, but it is one which requires careful fitting. It is dependent mainly upon preparing special gigs and forms for rolling out the strips and turning them to exact sizes, and calking them into position. With the gigs and forms at hand the work becomes comparatively simple, and can be accomplished without removing the shaft from the ship. The examination of the glands of this turbine showed one snap ring to be broken, though the ring was still operative. It appeared to be caused by a flaw in the material.

Another item which may be of interest and which was undertaken by the ship's force was the overhauling of the expansion couplings in No. 2 and No. 3 shafts. These couplings are fitted between the sections of shaft which carry the cruising turbines and the remainder of the shafting. They are as shown in Figure I, G. They are intended to work sufficiently loose to prevent propeller thrust being thrown on the cruising-turbine thrust blocks, but the coupling in No. 3 shaft was originally made a driving fit and has never functioned satisfactorily. In consequence the lower half of the intermediate-pressure cruising thrust block has had propeller thrust thrown on it and has heated up on several occasions, and scorched. This coupling was overhauled and the faces of the coupling teeth ground down slightly with an emery wheel. It should be stated, perhaps, that this coupling is of the single type, whereas it might prove more effective to install types capable of free motion at either end.

In closing these remarks it might be well to mention what experience has been had with water carrying over to the turbines with the steam. Such experiences have been very rare, as the boilers supply dry steam and as the drainage provisions are generally very satisfactory; but one instance can be mentioned. Over a year ago the turbines were given a twelve-hour full-power trial under the intermediate-pressure cruising-turbine combination, it being intended to find out whether this was feasible and economical under two-thirds boiler power. Near the end of the trial careless water tending resulted in sudden

and excessive priming, and the I.P.C. turbine received an abnormal load of water which caused it to slacken its speed momentarily to a marked extent, but which did no apparent damage. Since that time this turbine has never failed to run normally and has undergone numerous severe tests, including the water-rate test for economy. The blades in the first stage of this turbine are of $1\frac{1}{8}$ inches height, and are secured by lacing strips in addition to being regularly calked into place.

During the past month new propellers of Bureau design have been installed on the *Chester*. They have not as yet been given a trial but better results than ever are looked for. The comparison of the dimensions of the old and new propellers are as follows:

PROPELLER DATA.

	Old.	New.
Type and material, . Solid, true-screw, manganese-bronze.		
Number of propellers, ...	4	4
Number of blades, each, ...	3	3
Diameter, feet and inches, ...	6–0	6–9
Pitch, as set, mean, feet and inches, . .	6–0	6–0
Ratio of diameter to pitch, ...	1.0	1.125
Area, projected, square feet, ...	17.02	19.7
helicoidal, square feet, ...	19.0	22.3
disk, ...	28.27	35.68

The modifications are believed to be along the same lines as the later types recommended by the Parsons Turbine Company, though not so in all respects.

LATER NOTES.

A short run, during which the speed was divided between 15, 16 and 17 knots, offered a slight chance to observe the action of the propellers above referred to and also the action of the starboard astern turbine after being assembled.

As regards the propellers, no change in speed could be noticed for the same number of revolutions per minute as used with the old screws, at the above speeds, though of course the

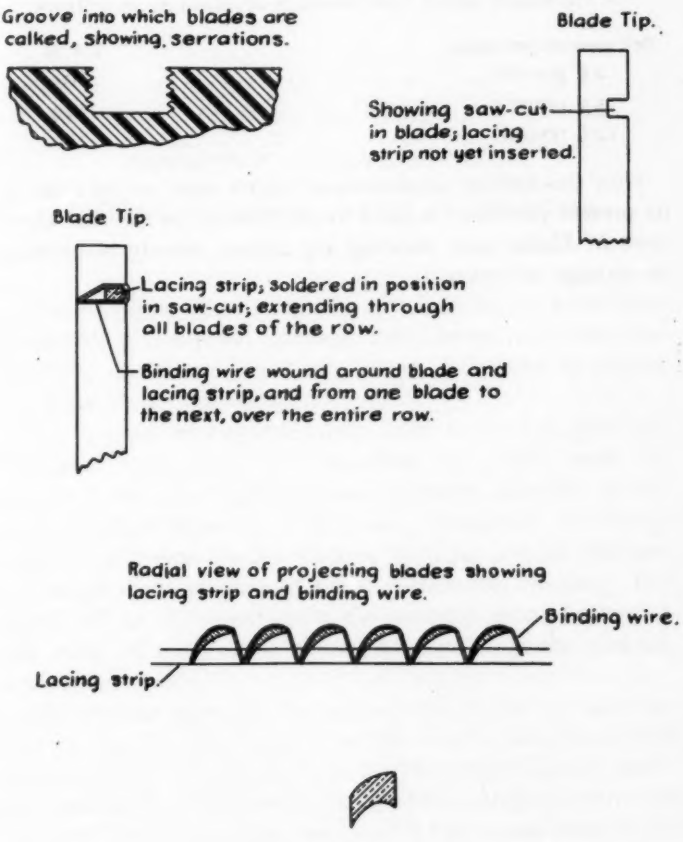

Groove into which blades are calked, showing serrations.
Blade Tip.
Showing saw-cut in blade; lacing strip not yet inserted.
Blade Tip.
Lacing strip, soldered in position in saw-cut; extending through all blades of the row.
Binding wire wound around blade and lacing strip, and from one blade to the next, over the entire row.
Radial view of projecting blades showing lacing strip and binding wire.
Binding wire.
Lacing strip.
Type of calking piece.

Fig. IV.

ship was not accurately standardized. Considerable loss in economy at these speeds resulted, and the hull vibration proved much more marked in the vicinity of the engine room than ever before. Certain spring bearings which had never before run warm heated very slightly on starting out.

The starboard astern turbine made revolutions as follows:

Belt pressure per gauge.	R.P.M.
25 pounds	105
55 pounds	144
125 pounds	226

How this turbine can develop as high a speed as the latter in its present condition is hard to understand, as the first three rows of blades now standing are almost entirely blanked to the passage of steam.

U. S. S. *MICHIGAN.*

DESCRIPTION AND OFFICIAL TRIALS.

By William Ashley Leavitt, Jr., Associate.

The *Michigan* (Battleship No. 27), built by the New York Shipbuilding Company, Camden, New Jersey, is a first-class battleship of 16,000 tons displacement, authorized by Act of Congress March 3d, 1905.

The contract was awarded July 20th, 1906; first plate laid December 17th, 1906; hull launched May 26th, 1908, the sponsor being Miss Carol Barnes Newberry, daughter of the then Assistant Secretary of the Navy, Truman H. Newberry, there being present the Governor of Michigan and his staff and a distinguished company of naval officers and citizens. The vessel will be delivered to the Government about September 1st, 1909, or about three months in advance of the contract time, forty months.

The contract price for the construction of the hull and machinery was $3,585,000.00, of which sum $2,660,000.00 was allotted to hull and $925,000.00 for the propelling and auxiliary machinery. The contract required an average speed of not less than 18½ knots in the open sea for four consecutive hours, at a mean draught of 24 feet 6 inches, corresponding to a displacement of 16,000 tons; and twenty-four-hour endurance and coal-consumption trials under the same conditions at 17½ and 12 knots speed, making in all a very exhaustive series of trials. As outlined in detail in this article, these trials were all accomplished most successfully, and the vessel is undoubtedly the fastest and best battleship in the Navy—a great credit to the builders and the several departments of the U. S. Navy concerned in the work.

OFFICIAL TRIALS.

The Navy Department having given permission to begin the official trials, June 9th, 1909, the ship left Camden June 6th, at 11 A. M., raching Rockland, Maine, at 9 A. M. June 8th. The trip was devoid of interest, the performance of the propelling machinery being generally very satisfactory. June 9th being favorable as regards weather conditions, the standardization runs were made over the Government measured-mile course off Monhegan Island, the maximum speed attained being at the rate of 20.06 knots, at 125.64 average revolutions, developing 19,204 I.H.P. for the main engines and 19,680 I.H.P. for all machinery. The average of the five full-power runs was 19.11 knots, at 121.18 average revolutions, developing 16,425 I.H.P. for the main engines and 17,007 I.H.P. for all machinery.

On June 10th, beginning at 11:38 A. M. the four-hour endurance run in open sea was made most successfully, the course being laid S.S.W.¾W., along the New England coast.

At the conclusion of the four-hour run, at 3:38 P. M., the twenty-four-hour 17½-knot run was begun, but was stopped at 6 P. M. to overhaul the reducing valve on steam line to steering engine. While this work was under way a heavy fog settled down, and vessel had only been under way a short time when she ran aground at 10:35 P. M. on a bar about 300 yards from the shore and about two miles southwest of Cape Cod light. Fortunately the grounding occurred at low water, and at 1 A. M. the tide had risen so that the ship succeeded in backing off and proceeded to Provincetown harbor to clean out sea connections and water-service pipes.

Reached Provincetown at 11 A. M., June 11th, remaining there until 9:30 A. M., June 12th, when anchor was weighed and the vessel proceeded to sea again, beginning what was to be the required twenty-four-hour run at 12 knots at 11 A. M. At 4 P. M. the run was called off, as it was found that the starboard engine was developing about 1,000 more horsepower than the port engine to maintain the same number of revolutions, due to damaged propeller blades and sand in strut and

stern-tube bearings. Proceeding homeward the vessel reached Camden at 9 A. M., June 14th. Upon docking the vessel at the Philadelphia Navy Yard it was ascertained that the blades of both propellers were damaged, those for the starboard side being the worst; and the casing over the starboard propeller shaft in the strut bearing had a very perceptible sand-worn shoulder on it, the lignum vitae strips in all strut and stern-tube bearings also showing sand wear. The propellers, propeller and stern-tube shafting and all bearings were removed and taken to the company's shops, and between the dates June 17th and July 18th new propeller blades were cast and machined and all other parts mentioned overhauled and replaced, and the vessel proceeded to the Delaware Capes, July 20th, for a continuation of the trials.

July 21st a series of six standardization runs were made over a measured course outside the Delaware Capes, the results being approximately the same as were obtained under similar conditions over the Rockland course.

July 22d at 6:28 A. M. the twenty-four hour 17½ knot run was begun from the Five Fathom Bank Light Ship, the course being S.E. by S., this run being completed at 6:28 A. M., July 23d; the twenty-four-hour 12-knot and final run of the trials began at 10:42 A. M. of the same date, being finished at the same hour July 24th, after which the steering gear was given the prescribed tests on the run in to the Delaware Capes.

Below will be found general data of the four trial runs in the order mentioned.

STANDARDIZATION.

For the purpose of standardizing the screws seventeen runs were made over the measured-mile course off Monhegan Island June 9th, 1909. Previous to the starting of the standardization runs the draught was taken and found to be:

Forward, feet and inches	24–01¼
Aft, feet and inches	25–00¼
Mean, feet and inches	24–06¾
Corresponding displacement, tons	16,065

These runs gave the data from which curves on Fig. 1 were plotted.

DATA FOR FOUR-HOUR RUN.

Draught at beginning of trial, forward, feet and inches..	24–01½	
aft, feet and inches.....	25–02½	
Mean draught at beginning of trial, feet and inches.....	24–07$\frac{13}{16}$	
Corresponding displacement at mean draught at beginning of trial, tons.....	16,135	
Mean draught at end of trial, feet and inches, (3:38 P. M.)	24–06	
Corresponding displacement at mean draught during trial, tons.....	16,064	
Speed of ship, in knots per hour.....	18.788	
	Starboard.	*Port.*
Slip of propellers, in per cent. of their speed.....	11.44	11.48

Steam Pressures. (*Average of one-half hourly observations.*)

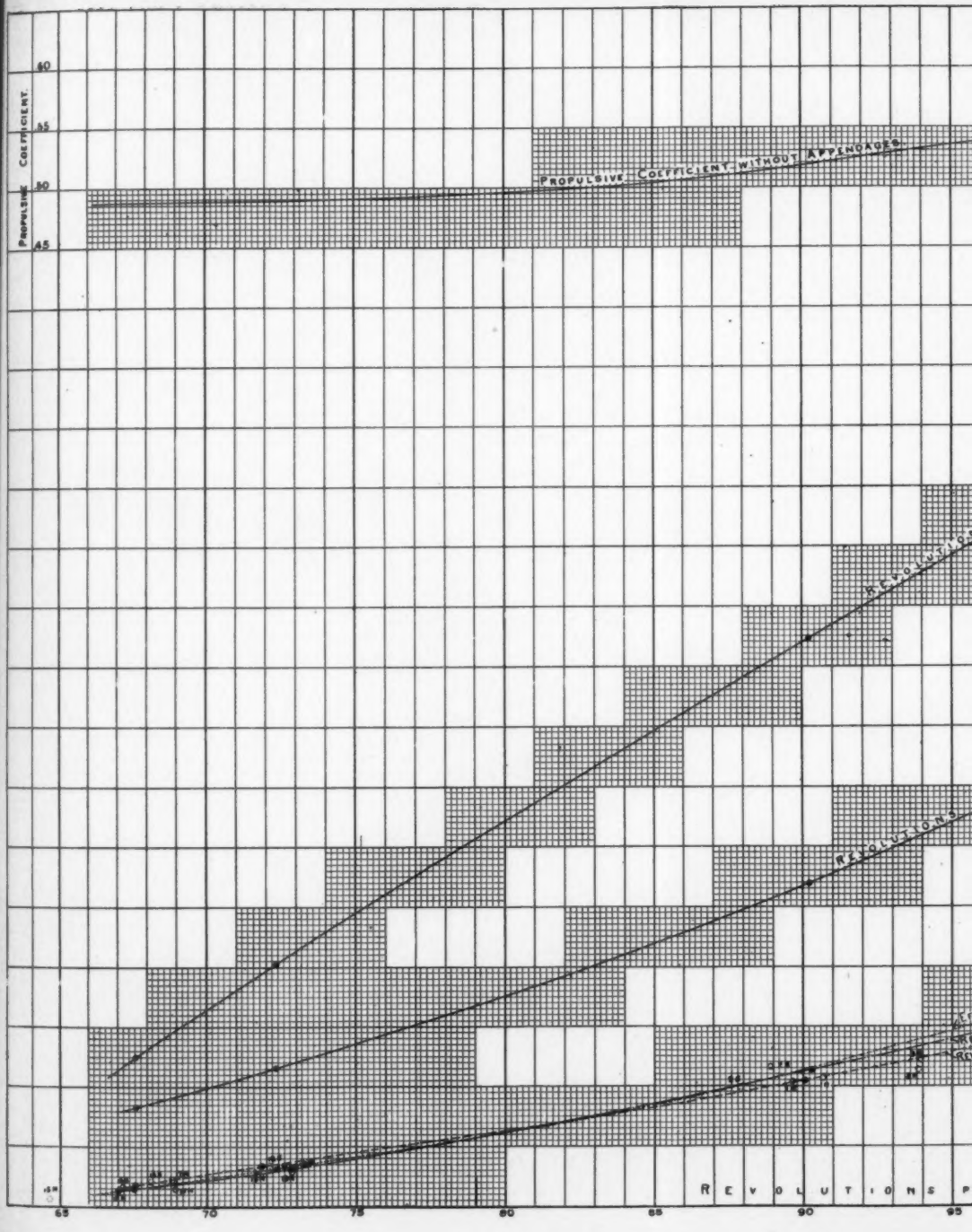
Maximum steam pressure of boilers, pounds.....	310.0	
Mean steam pressure at boilers, pounds.....	297.7	
Maximum steam pressure at engines, pounds.....	288.0	287.0
Mean steam pressure at engines, pounds.....	281.5	282.9
H.P. steam chest, gauge, pounds	253.4	238.0
1st receiver (absolute), pounds..	71.38	83.38
2d receiver (absolute), pounds...	7.41	8.8
degrees of superheat of steam at H.P. steam chest	88.5	82.7
Vacuum in condensers, inches of mercury, mean.....	27.06	26.87
maximum...	27.2	27.0

Temperatures. (*Average on one-half hourly observations.*)

Injection, degrees.....	49.25	49.25
Discharge, degrees.....	84.63	79.75
Hotwell, degrees.....	100.0	103.0
Feed water, degrees.....	149.63	161.5
Outside air, degrees.....	57.0	
Engine room, working platform, degrees.....	91.25	91.88
Fireroom, working level, degrees.....	104.5	
Smoke stacks, average, degrees.....	555.0	

Revolutions or Double Strokes per minute. (*Average of one-half hourly observations.*)

Average revolutions, main engines, per minute...	119.43	119.49
Mean revolutions, both engines, per minute.....	119.46	
Pumps, main air.....	27.75	28.5
circulating.....	181.25	163.5
feed, d.s. per minute.....	16.27	14.7
fire and bilge.....	Not run.	
dynamo condenser circulating.....	174.7	.....


PROPULSIVE COEFFICIENT
.60
.55
.50
.45
PROPULSIVE COEFFICIENT WITHOUT APPENDAGES
REVOLUTIONS
65
70
75
80
85
90
95

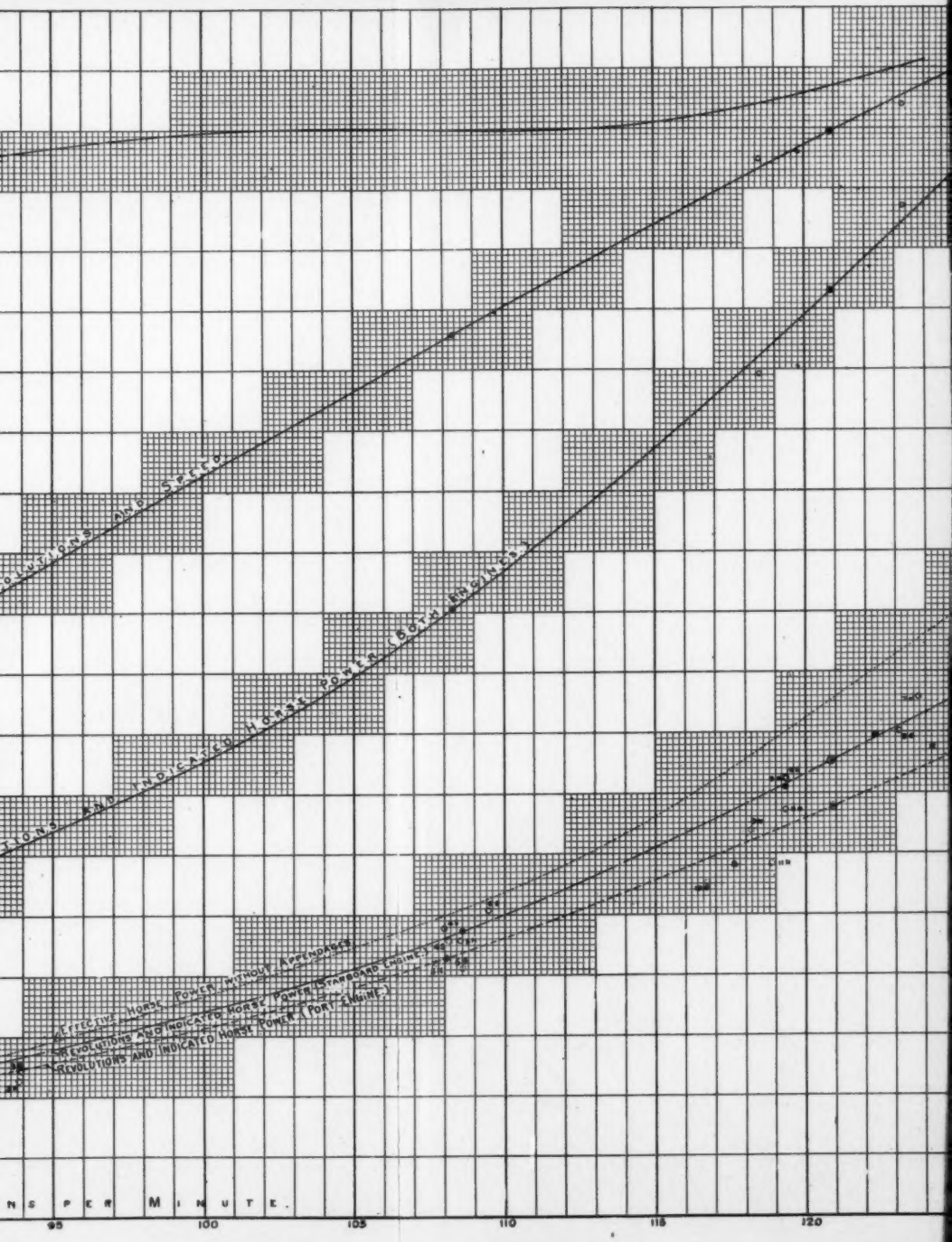

REVOLUTIONS AND INDICATED HORSE POWER (BOTH ENGINES)
REVOLUTIONS AND INDICATED HORSE POWER (STARBOARD ENGINE ONLY)
REVOLUTIONS AND INDICATED HORSE POWER (PORT ENGINE)
EFFECTIVE HORSE POWER WITHOUT APPENDAGES
95
100
105
110
115
120
PER MINUTE.

Fig. I.

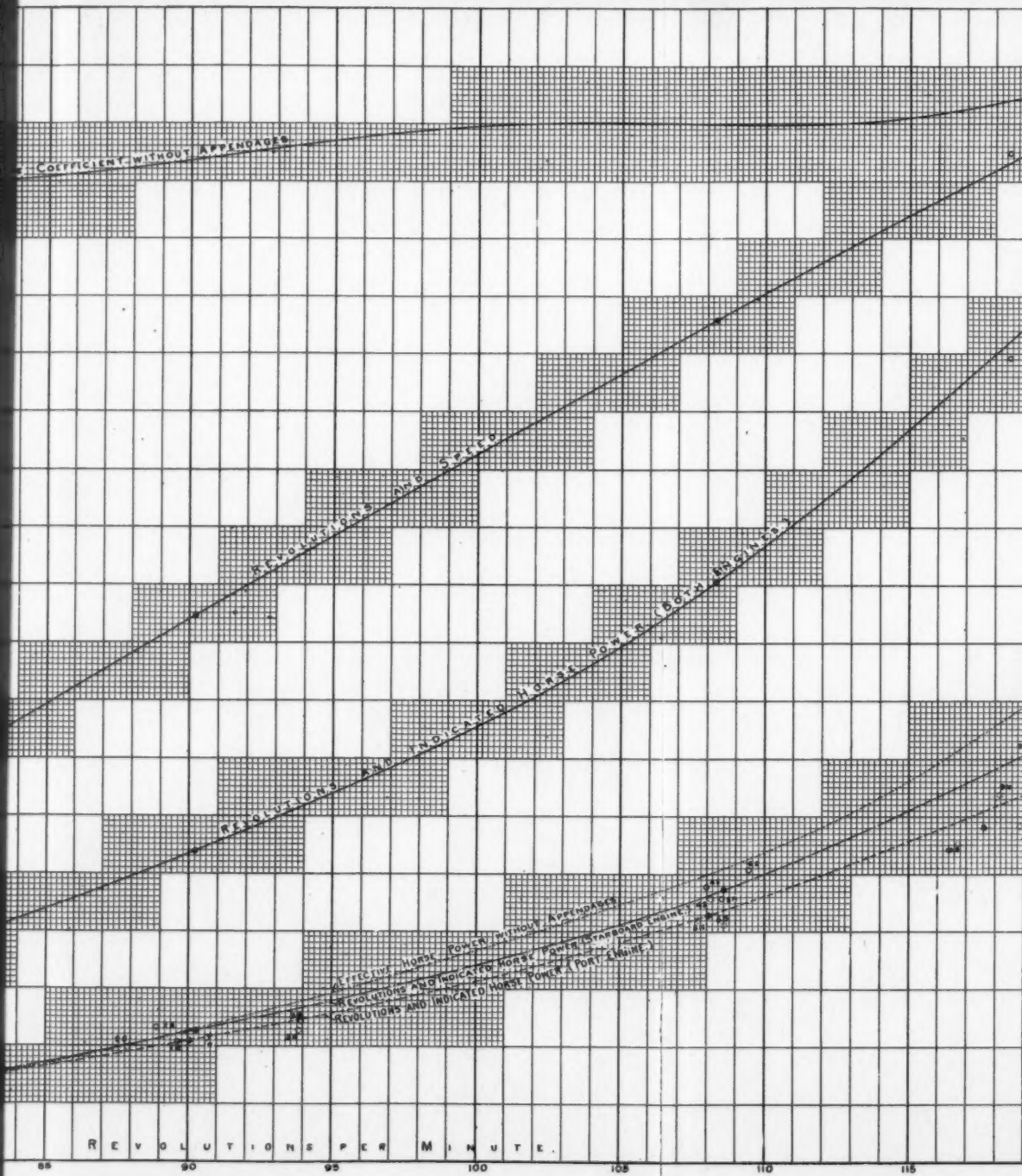
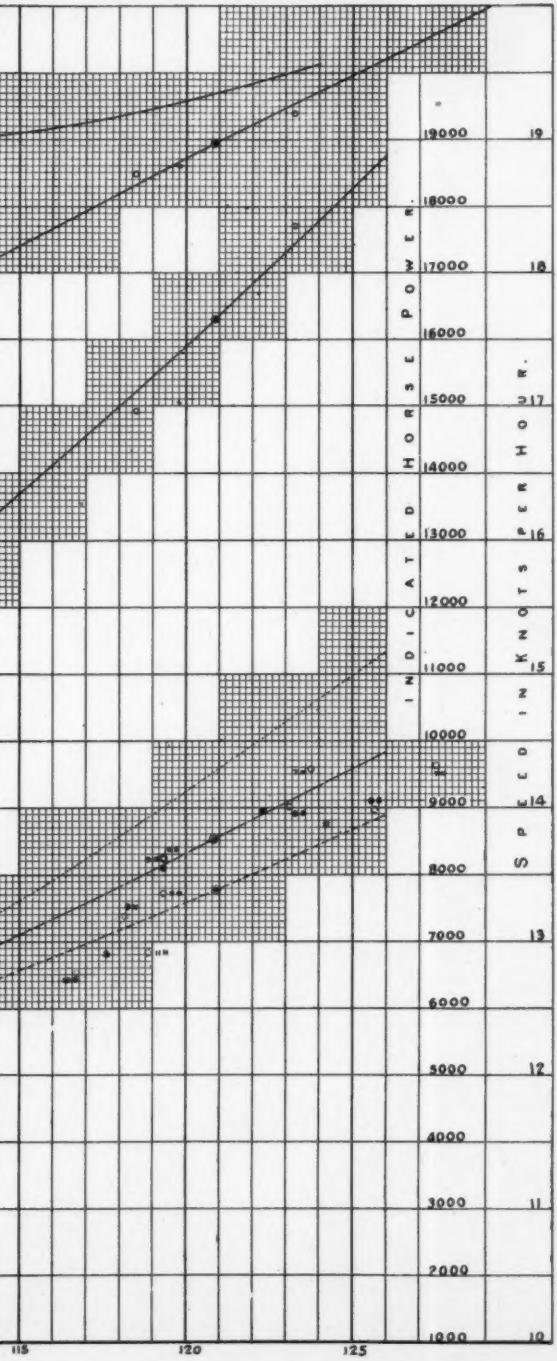

C Coefficient without Appendages
Revolutions and Speed
Revolutions and Indicated Horse Power (Both Engines)
Revolutions and Indicated Horse Power (Port Engine)
Effective Horse Power without Appendages
Revolutions and Indicated Horse Power (Starboard Engine)
Revolutions and Indicated Horse Power (Port Engine)
Revolutions per Minute.
85
90
95
100
105
110
115

Fig. I.



No. of Runs	R.P.M. Starb.	R.P.M. Port	R.P.M. Mean Both	I.H.P. Starb.	I.H.P. Port	I.H.P. Total Both	Speed in Knots per Hour.
1-N	89.66	90.67	90.17	3066	3137	6203	15.248
2-S	88.89	87.87	88.38	3317	2999	6316	15.934
3-N	93.93	93.83	93.88	3440	3282	6722	15.769
4-S	91.39	90.15	90.77	3536	3581	7117	16.613
5-N	88.50	90.17	89.34	3384	3719	7103	17.964
6-S	90.46	88.81	89.64	3697	3538	7232	16.651
7-N	123.79	127.49	125.64	9572	9632	19204	20.067
8-S	123.40	125.64	124.52	9009	8988	17997	18.692
9-N	119.35	118.15	118.75	8228	7390	15618	19.334
10-S	119.34	116.72	118.03	8240	6531	14771	18.191
11-N	119.32	118.33	118.82	7711	6827	14538	19.272
12-S	72.83	72.04	72.44	3663	3709	7372	11.316
13-N	72.84	71.74	72.29	3597	3611	7208	12.539
14-S	72.65	71.85	72.25	3678	3712	7390	11.502
15-N	66.99	64.61	65.75	2713	2726	5439	11.434
16-S	67.19	65.10	67.65	3529	3420	6949	10.672
17-N	68.92	68.79	68.86	3705	3452	7157	11.796

Diameter	17ft 6in
Pitch	18ft 0 ins.
Helicoidal area	89.19 sq ft
Projected area	75.97 sq ft
Hel. area / Proj. area	.369

U.S.S. MICHIGAN.

STANDARDIZATION RUNS.

ROCKLAND MAINE.

JUNE 9, 1909.

BUREAU OF STEAM ENGINEERING
NAVY DEPARTMENT
WASHINGTON, D.C.

	Starboard.	Port.
Dynamo turbine	1,678.0	
Forced-draft blowers	646.0	
Air pressure in firerooms, in inches of water, mean	.67	

Mean Effective Pressures in Cylinders, in pounds per square inch. (Averages of cards taken at half-hourly periods.)

Main engines, H.P. cylinder	104.74	106.28
I.P. cylinder	48.24	48.03
F.L.P. cylinder	10.78	11.14
A.L.P. cylinder	11.75	12.0
Mean equivalent pressure, in pounds per square inch, referred to combined area of L.P. pistons	34.14	34.32

Indicated Horsepower.

Main engines, H.P. cylinder	2,379.75	2,412.8
I.P. cylinder	2,938.75	2,926.6
F.L.P. cylinder	1,264.42	1,307.5
A.L.P. cylinder	1,378.13	1,408.5
total	7,961.05	8,055.4
Collective H.P. of both main engines	16,016.45	
Air pumps, main, average each	14.82	
Circulating pumps, main, average each	89.4	
Feed pumps, main, average each	51.4	
Dynamo condenser, circulating pumps, average each	5.0	
Dynamo engine and forced-draft blowers	191.5	
Total for all auxiliaries	500.85	
Collective I.H.P. main engines, air, circulating and feed pumps	16,313.55	
Main and auxiliary engines in operation	16,517.3	

Coal.

Kind and quality used on trial	Pocahontas hand-picked; excellent.
Pounds per hour, main and auxiliary engines, during trial	24,139

Deduced Data.

I.H.P. (total) per square foot of grate surface	15.76
main engines, air, circulating and feed pumps, per square foot of grate surface	15.57
main engines, air, circulating and feed pumps, per square foot of heating surface	2.89
Pounds of coal per I.H.P. per hour, main engines	1.51
all machinery in operation	1.46
square foot of grate surface, per hour	23.28
square foot of heating surface, per hour	0.511
Cooling surface (main condenser), square feet per I.H.P. (main engines)	1.15
Heating surface, square feet per I.H.P. (total)	2.81

DATA FOR TWENTY-FOUR-HOUR RUN AT 17¼ KNOTS.

Draught at beginning of trial, forward, feet and inches	24-02⅜	
aft, feet and inches	25-03⅜	
Mean draught on trial, feet and inches	24-07½	
Displacement at mean draught on trial, tons	16,080	
Speed of ship, in knots per hour	17.95	
	Starboard.	*Port.*
Slip of propellers, in per cent. of their speed	10.17	10.13

Average Steam Pressures.

Mean steam pressure at boilers, pounds	231.0	
engines, pounds	217.0	217.0
H.P. steam chest, gauge, pounds	198.0	200.0
1st receiver (absolute), pounds	77.0	86.0
2d receiver (absolute), pounds	20.0	20.0
Mean degrees superheat H.P. chest	73.26	
Vacuum in condensers, inches of mercury, mean	26.97	26.93

Average Temperatures.

Injection, degrees	76	
Discharge, degrees	106	
Hotwell, degrees	Not taken.	
Feed water, degrees	161	131
Outside air, degrees	74	
Engine room, working platform, degrees	99	99
Fireroom, working level, degrees	109	
Smoke stacks, average, degrees	545	

Average Revolutions or double strokes per minute.

Average revolutions, main engines, per minute	112.489	112.443
Mean revolutions, both engines, per minute	112.466	
Pumps, main air	30.8	31.2
circulating	176.0	176.0
feed, d.s. per minute	7.84	11.92
dynamo condenser, circulating	172.0	
dynamo air	38.0	
Dynamo turbine	1,674.0	
Forced-draft blowers	692.0	
Air pressure in firerooms, in inches of water, mean	0.64	

Mean Effective Pressures in Cylinders, in pounds per square inch.

Main engines, H.P. cylinder	88.9	91.9
I.P. cylinder	42.3	41.9
F.L.P. cylinder	9.91	9.99
A.L.P. cylinder	10.57	10.0
equivalent pressure, in pounds per square inch, referred to combined area of L.P. pistons	29.81	29.77

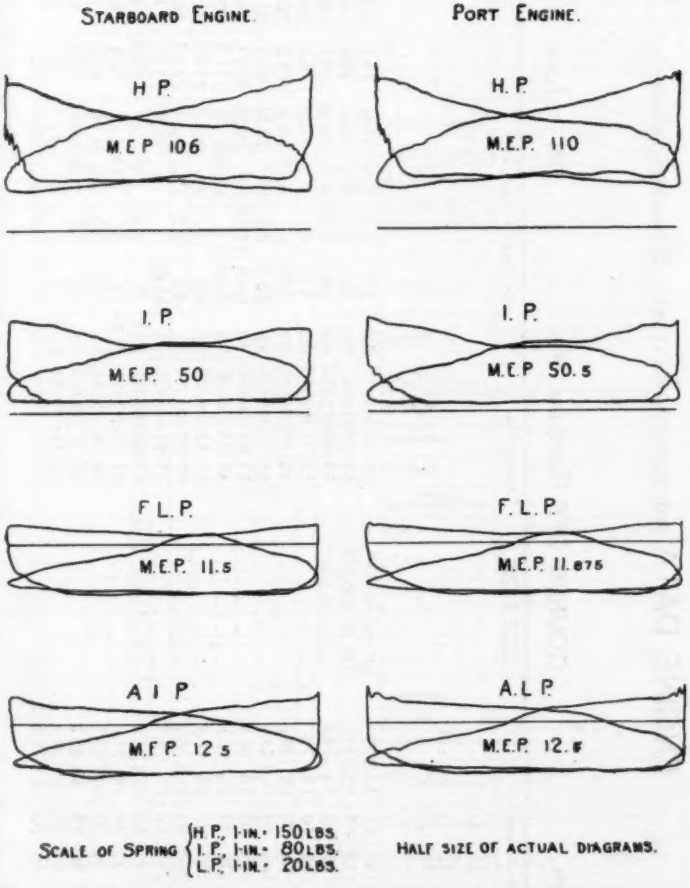


Fig. 2.—SET OF INDICATOR CARDS. FOUR-HOURS' FULL-POWER TRIAL.

Trial (a) Data.
Sheet 3.

Starboard ENGINE DATA (ONE SHEET FOR EACH ENGINE), Standardization TRIALS.

U. S. S. Michigan, COURSE OFF Rockland Me., ON June 9, 1909

Number of run or observation.	Time. H.	M.	S.	Reading of engine counter.	Revolutions per min.	Steam pressure. At engine, per gage.	H. P. steam chest per gage	I. P. receiver abs. lbs.	L. P. receiver abs. lbs.	Vacuum in inches, mercury.	Barometer.	Cut-off in cyl. in decimal of stroke. H. P.	I. P.	F. L. P.	A. L. P.	Temperature. Outside air.	Engine room working level.	Injection.	Discharge.	Hot well.	Feed (entering boilers).	Mean effective pressure. H. P. cyl.	I. P. cyl.	F. L. P. cyl.	A. L. P. cyl.	Referred pressure.	Indicated horsepower. H. P. cyl.	I. P. cyl.	F. L. P. cyl.	A. L. P. cyl.	Total.
1				89.66	275	120	47	13.5	27.			full	full	full	full			49	67	134	171	55.	25.	5.4	5.8	17.41	937	1143	475	511	3066
2				88.89	274	125	49	13.5	27.			.778	.702	.603	.607			49	67	120	162	59.	31.	5.	5.5	19.01	996	1405	436	480	3317
3				93.93	278	135	53	14.	26.7			"	"	"	"			49	67	112	150	60.	36.	5.15	4.5	20.28	1071	1724	530	415	3740
4				107.98	280	195	70	19.	29.			"	"	"	"			49	71	108	148	86.	37.5	9.	9.	27.05	1764	2064	954	954	5736
5				108.50	278	195	70	19.	26.7			"	"	"	"			49	72	108	170	87.	36.37	8.	8.75	26.24	1793	2012	852	932	5589
6				109.46	285	205	73	19.5	26.5			"	"	"	"			49	72	108	158	92.	39.33	8.5	10.	28.36	1913	2195	914	1075	6097
7				123.79	274	255	98	26.	26.3			"	"	"	"			49	83	108	148	130.	54.6	12.25	13.	39.36	3057	3446	1489	1580	9572
8				123.10	278	270	98	26.	26.1			"	"	"	"			49	83	106	158	116.	51.66	12.	13.25	37.51	2713	3243	1451	1602	9009
9				119.35	288	260	91	24.	26.7			"	"	"	"			49	82	106	168	112.	49.	11.	12.	35.05	2539	2982	1301	1406	8228
10				119.34	282	260	92	24.5	26.7			"	"	"	"			49	82	105	160	121.	47.	10.5	12.	35.15	2743	2860	1231	1406	8240
11				119.32	273	250	90	24.	26.3			"	"	"	"			49	81	105	152	104.	45.63	11.	11.	32.90	2357	2776	1289	1289	7711
12				72.93	252	75	36	10.7	27.2			"	"	"	"			49	58	86	186	37.5	19.	2.6	3.5	11.61	520	706	186	251	1663
13				72.84	251	72	34	10	27.1			"	"	"	"			49	58	112	198	37.5	17.	3.	3.25	11.17	519	631	215	232	1597
14				72.65	253	74	37	10.7	27.2			"	"	"	"			49	58	110	196	33.	19.5	3.5	3.5	11.75	456	722	250	250	1678
15				66.99	251	60	29	8.5	29.2			"	"	"	"			48	57	110	196	30.	16.	2.5	2.75	9.68	382	546	164	181	1273
16				67.19	250	60	32	9.	29.2			"	"	"	"			48	57	112	194	27.5	17.	3.	3.	10.07	351	582	198	198	1329
17				68.92	255	60	32	8.7	29.2			"	"	"	"			48	57	110	148	25.	16.75	2.75	3.	9.65	327	589	186	203	1305
*Total.																															
*Average.																															

Trial (Q) Data Sheet 8.

Port ENGINE DATA (ONE SHEET FOR EACH ENGINE), Standardization TRIALS.

U. S. S. Michigan, COURSE OFF Rockland, Me., ON June 9, 1909.

Number of run or observation	Time H.	Time M.	Time S.	Reading of engine counter	Revolutions per min.	Steam pressure: At engine, per gage	Steam pressure: H. P. steam chest per gage	Steam pressure: I. P. receiver abs. lbs.	Steam pressure: L. P. receiver abs. lbs.	Vacuum in inches, mercury	Barometer	Cut-off in cyl. in decimal of stroke: H. P.	Cut-off: I. P.	Cut-off: F. L. P.	Cut-off: A. L. P.	Temperature: Outside air	Temperature: Engine room, working level	Temperature: Injection	Temperature: Discharge	Temperature: Hot well	Temperature: Feed, entering column	Mean effective pressure: H. P. cyl.	Mean effective pressure: I. P. cyl.	Mean effective pressure: F. L. P. cyl.	Mean effective pressure: A. L. P. cyl.	Mean effective pressure: Referred pressure	Indicated horsepower: H. P. cyl.	Indicated horsepower: I. P. cyl.	Indicated horsepower: F. L. P. cyl.	Indicated horsepower: A. L. P. cyl.	Indicated horsepower: Total
1					90.67	280	120	57	13.5	27.		.778	.701	.603	.607	60		47	62	125		54.	27.5	5.25	5.25		930	1271	468	468	3137
2					87.87	280	112	55	13.5	27.		"	"	"	"	60		50	64	118		53.5	27.0	5.375	5.00		893	1210	464	432	2999
3					93.83	282	115	53	13.5	27.		"	"	"	"	56		48	68	118		54.5	26.5	5.00	5.825		971	1268	507	536	3282
4					108.15	280	180	77	13.	28.5		"	"	"	"	58		47	69	100		80.5	37.5	8.50	9.00		1654	2068	903	956	5581
5					107.73	273	183	75	18.5	26.5		"	"	"	"	56		48	68	100		83.75	33.25	8.00	7.875		1714	1826	846	833	5219
6					108.61	284	192	78	19.5	26.5		"	"	"	"	56		48	69	98		84.5	29.0	8.00	8.75		1743	1606	853	933	5135
7					127.49	270	260	117	29.	26.		"	"	"	"	54		46	80	104		109.5	52.5	14.00	14.50	38.47	2652	3412	1753	1815	9632
8					125.64	275	265	115	28.5	26.		"	"	"	"	62		48	79	100		111.0	45.0	13.50	14.50	36.42	2650	2883	1666	1789	8988
9					118.15	290	230	91	22.5	26.5		"	"	"	"	56		46	70	100		104.0	43.5	10.00	11.00	31.85	2334	2620	1160	1276	7390
10					116.72	285	225	88	21.5	26.5		"	"	"	"	62		47	70	102		102.5	34.0	9.50	10.00	28.49	2273	2023	1089	1146	6531
11					118.87	273	235	94	23.5	25.5		"	"	"	"	56		45	71	100		106.75	30.5	10.75	11.25	29.25	2411	1848	1255	1313	6827
12					72.04	255	72	41	10.55	26.		"	"	"	"	60		49	57	96		32.5	19.75	3.87	3.75	12.09	445	725	274	265	1709
13					71.74	252	65	38	10.25	26.		"	"	"	"	56		47	57	96		36.5	19.0	3.20	2.75	11.44	497	695	225	194	1611
14					71.85	255	75	39	10.55	26.5		"	"	"	"	54		48	58	100		40.5	19.8	3.375	3.625	16.06	553	725	238	256	1772
15					64.61	254	49	32	8.75	28.		"	"	"	"	58		48	56	99		25.25	14.5	2.56	2.78	8.87	310	478	162	176	1126
16					68.10	250	62	35	9.50	28.		"	"	"	"	64		48	57	104		32.5	16.75	3.12	3.12	10.61	420	582	209	209	1420
					69.79	253	63	34	9.25	28.5		"	"	"	"	56		48	58	103		33.0	16.94	3.00	3.00	10.59	437	603	206	206	1452
*Total.																															
*Average.																															

Standardization TRIAL.

Trial (9) Data, Sheet 4.

AUXILIARIES—REVOLUTIONS OR DOUBLE STROKES.

U. S. S. Michigan, COURSE OFF Rockland, Me., ON June 9, 1909

Number of Run or Observation.	Revolutions or Double Strokes.																				
	Pumps, Starboard.								Pumps, Port.								Pumps.			Dynamo engines.	F. D. blowers.
	Main air.	Main circulating.	Main feed.	Oil feed.	Hot well.	Fire and bilge.	Water service.	Auxiliary condenser.	Main air.	Main circulating.	Main feed.	Oil feed.	Hot well.	Fire and bilge.	Water service.	Auxiliary condenser.	Dynamo Oil	Sanitary.	Dynamo condenser.		
1	26	158	20						28	168	3.5	0		0		0	46		195	1700	
2	30	158	20						32	176	3.	60		0		0	45		192	1700	
3	30	150	21						32	170	0	0		0		0	45		191	1700	
4	30	170	23						40	181	0	0		0		0	46		194	1700	
5	30	160	11	Not Running		Not Running		Not Running	39	184	19.	0		0		0	47		196	1700	
6	28	182	12				None		42	188	18.	0		0		0	45		197	1700	
7	28	180	22						41	186	21.	0		0		0	47		198	1700	
8	28	200	18						42	200	21.	0		60		0	47		198	1700	
9	28	196	12						40	200	20.	0		0		0	48		199	1700	
10	27	196	14						40	198	21.	0		0		0	48		195	1615	
11	27	178	15						39	196	19.	0		0		0	47		196	1615	
12	26	150	0						38	164	17.	0		30		0	47		195	1700	
13	26	140	0						36	140	15.	0		0		0	47		194	1700	
14	26	140	0						36	139	12.	0		0		0	46		185	1700	
15	27	146	0						35	145	10.	0		0		0	47		190	1700	
16	27	146	0						35	147	12.	0		0		0	46		192	1700	
17	27	146	16						37	150	11.	0		0		0	47		195	1700	
*Total.																					
*Average.																					

Standardization TRIAL.

Trial (G) Data. Sheet 8.

AUXILIARIES—INDICATED HORSEPOWER.

U. S. S. Michigan, COURSE OFF Rockland, Me., ON June 9, 1909.

		INDICATED HORSEPOWER OF AUXILIARIES.															
No. of run or observation.		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
PUMPS. Starboard.	Main air,	7.0	7.8	7.8	7.8	7.8	7.4	7.4	7.4	7.4	7.2	7.2	7.0	7.0	7.0	7.2	7.2	7.2
	Main circulating,	69.	69.	59.	85.	71.	105.	101.	136.	129.	129.	98.	59	48.5	48.5	55.	55.	55.
	Main feed,	65.	65.	68.	74.	38.	41.	71.	59.	41.	47	50	—	—	—	—	—	53.
	Feed,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Hot well,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Port.	Main air,	7.4	8.2	8.2	9.8	9.6	10.2	10.0	10.2	9.8	9.8	9.6	9.4	9.0	9.0	8.8	8.8	9.2
	Main circulating,	82.	95.	85.	103.	108.	115.	111.	136.	136.	133.	129.	77.	48.	47.	54.	56.	59.
	Main feed,	15.	13.	—	—	62.	59.	68.	68.	65.	68.	62.	56.	50.	41.	35.	41.	38.
	Feed,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Hot well,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Engine auxiliaries (total),		245.4	258.	228.	279.6	296.4	337.6	368.4	416.6	388.2	394.	355.8	208.4	162.5	152.5	160.	168.	221.4
Stard.	Water service,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Fire and bilge,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Auxiliary condenser,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Port.	Water service,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Fire and bilge,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Auxiliary condenser,	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dynamo condenser,		4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6	4.6
Sanitary. (Forwd. Electrical / Aft Steam pump(est))		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Dynamo oil (est)		1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Dynamo engines, *		87.03	87.03	87.03	87.03	87.03	87.03	96.52	208.17	208.17	206.65	206.65	100.53	122.88	167.56	167.56	167.56	161.56
F. D. blowers,		—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Steering engine (est.),		5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Other auxiliaries (total),		98.63	98.63	98.63	98.63	98.63	98.63	108.2	219.77	219.77	218.25	218.25	112.13	134.48	179.16	179.16	179.16	179.16
All auxiliaries (total),		344.03	356.63	326.63	378.23	395.03	436.23	476.6	636.37	607.97	612.25	574.05	320.05	296.98	331.66	339.16	347.16	400.56

Indicated Horsepower.

	Starboard.	Port.
Main engines, H.P. cylinder	1,908.0	1,984.0
I.P. cylinder	2,433.0	2,425.0
F.L.P. cylinder	1,100.0	1,114.0
A. L. P. cylinder	1,172.0	1,117.0
total	6,613.0	6,640.0
Collective H.P. of both main engines	13,253.0	
Air pumps, main, average each	15.5	
Circulating pumps, main, average each	90.0	
Feed pumps, main, average each	340.0	
Dynamo condenser, circulating pumps	4.2	
Dynamo engine and forced-draft blowers	221.0	
Total for all auxiliaries	514.8	
Collective I.H.P. main engines, air, circulating and feed pumps	13,517.0	
Collective main and auxiliary engines in operation	13,767.0	

Coal.

Kind and quality used on trial.....Pocahontas mixed with small percentage of George's Creek; good.

Pounds per hour, main and auxiliary engines, during trial. 22,442.0

Deduced Data.

I.H.P. (total) per square foot of grate surface	13.13
main engines, air, circulating and feed pumps, per square foot of grate surface	12.9
main engines, air, circulating and feed pumps, per square foot of heating surface	3.49
Pounds of coal per I.H.P. per hour, main engines	1.69
all machinery in operation	1.63
square foot of grate surface, per hour	21.41
heating surface, per hour	0.475
Cooling surface (main condenser), square feet per I.H.P. (main engines)	1.43
Heating surface, square feet per I.H.P. (total)	3.08

DATA FOR TWENTY-FOUR-HOUR RUN AT 12 KNOTS.

Draught at beginning of trial, forward, feet and inches	23-06⅜	
aft, feet and inches	25-07¼	
Mean draught on trial, feet and inches	24-05¾	
Displacement at mean draught on trial, tons	16,015	
Speed of ship, in knots per hour	12.05	
	Starboard.	*Port.*
Slip of propellers, in per cent. of their speed	5.32	5.25

Average Steam Pressures.

	Starboard.	*Port.*
Mean steam pressures at boilers, pounds	214.0	
engines, pounds	210.0	205.0
H.P. steam chest, gauge, lbs	69.2	77.0
1st receiver (absolute), pounds,	35.0	39.58
2d receiver (absolute), pounds,	10.94	9.15
degrees superheat, H.P. chest	51.0	
Vacuum in condensers, inches of mercury, mean	27.66	27.04

Average Temperatures.

Injection, degrees	71.0	
Discharge, degrees	85.0	
Hotwell, degrees	Not taken.	
Feed water, degrees	Not taken.	
Outside air, degrees	80.0	
Engine room, working platform, degrees	92.0	95.0
Fireroom, working level, degrees	104.0	
Smoke stacks, average, degrees	370.0	

Average Revolutions or double strokes per minute.

Average revolutions, main engines, per minute	71.644	71.596
Mean revolutions, both engines, per minute	71.62	
Pumps, main air	21.2	29.2
circulating	125.0	141.0
feed, d.s. per minute	Out.	9.52
dynamo condenser, circulating	205.0	
dynamo air	41.0	
Dynamo turbine	1,697.0	

Mean Effective Pressures in Cylinders, in pounds per square inch.

Main engines, H.P. cylinder	32.5	41.3
I.P. cylinder	19.75	19.18
F.L.P. cylinder	3.87	3.32
A.L.P. cylinder	3.95	3.22
Mean equivalent pressure, in pounds per square inch, referred to combined area of L.P. pistons	12.2	12.5

Indicated Horsepower.

Main engines, H.P. cylinder	444.0	567.0
I.P. cylinder	724.0	706.0
F.L.P. cylinder	272.0	236.0
A.L.P. cylinder	279.0	263.0
total	1,719.0	1,772.0
Collective H.P. of both main engines	3,491.0	
Total for all auxiliaries	306.0	
Collective I.H.P. main engines, air, circulating and feed pumps	3,621.0	
Collective main and auxiliary engines in operation	3,797.0	

Coal.

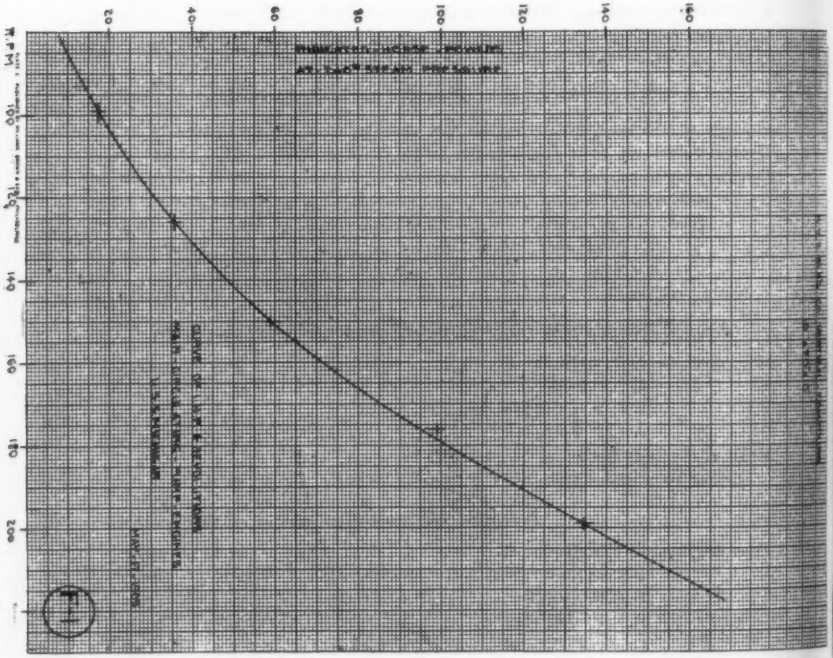
Kind and quality used on trial: Pocahontas, mixed with small percentage of George's Creek; good.

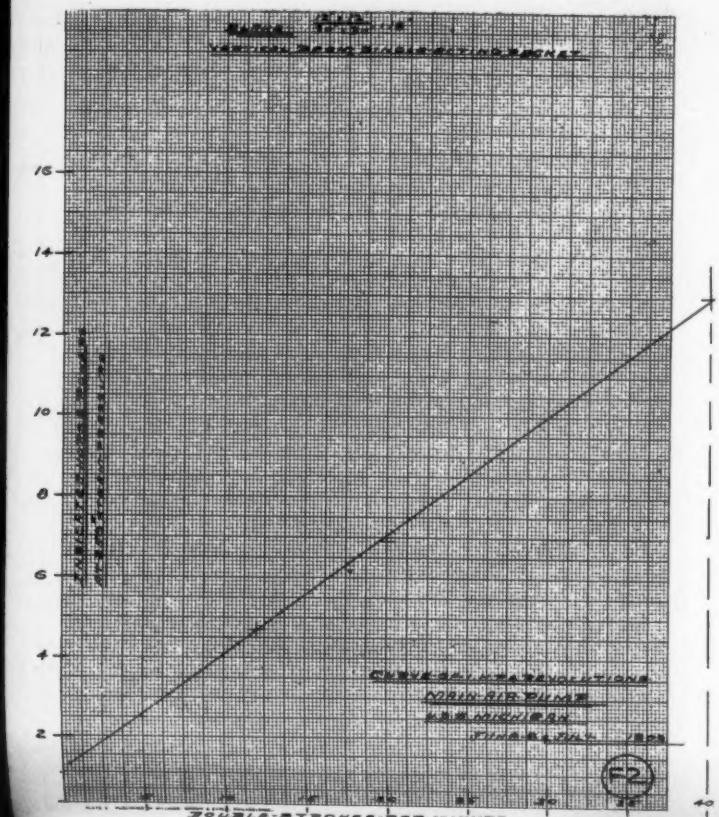
Pounds per hour, main and auxiliary engines, during trial..... 7,964

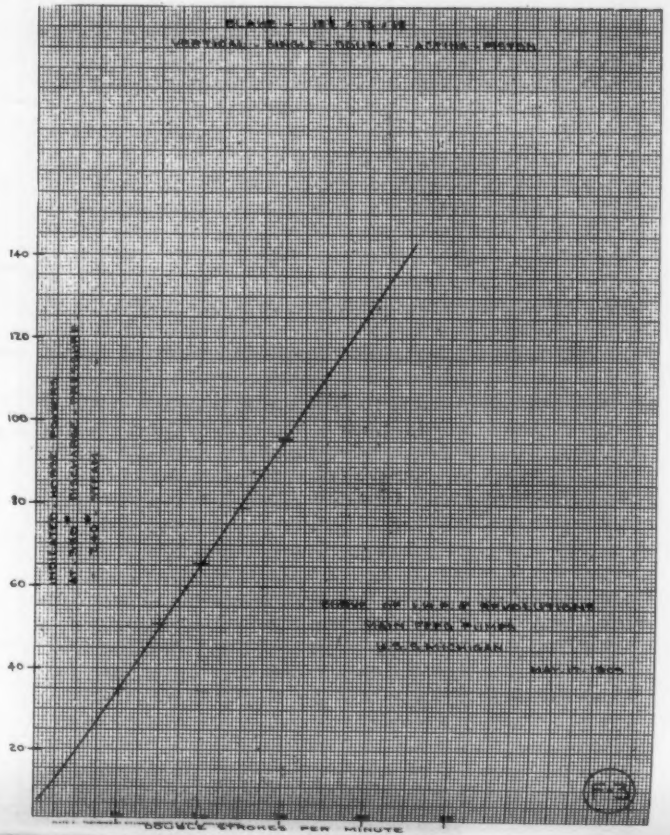
Deduced Data.

I.H.P. (total) per square foot of grate surface.....	5.43
heating surface..	7.46
Pounds of coal per I.H.P. per hour, collective, main engines.....	2.28
Pounds of coal per I.H.P. per hour, all machinery in operation.....	2.09
Pounds of coal per square foot of grate surface, per hour.....	11.49

NOTE.—Eight boilers in service for this run.

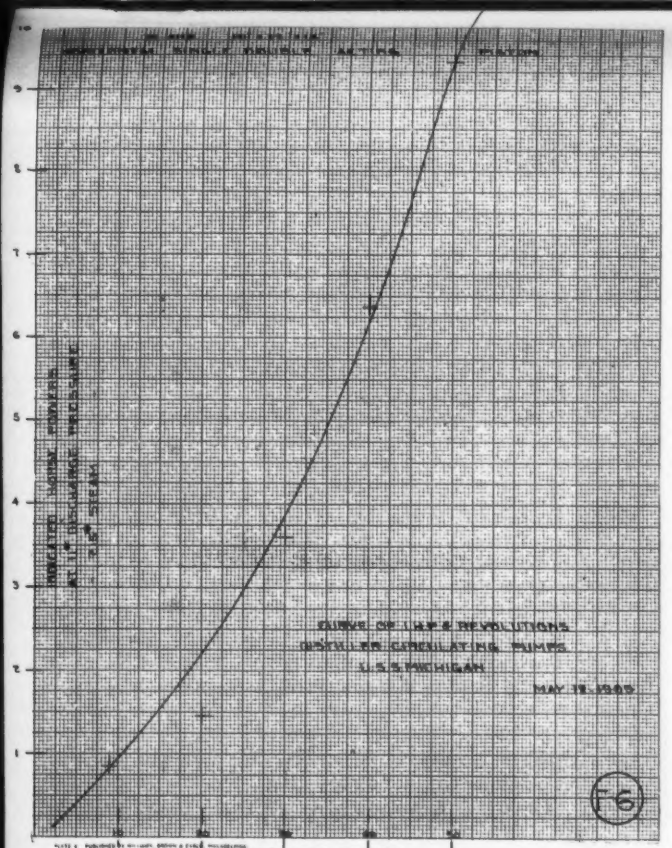



16
14
12
10
8
6
4
2
40
DOUBLE-STROKES-PER-MINUTE
F2

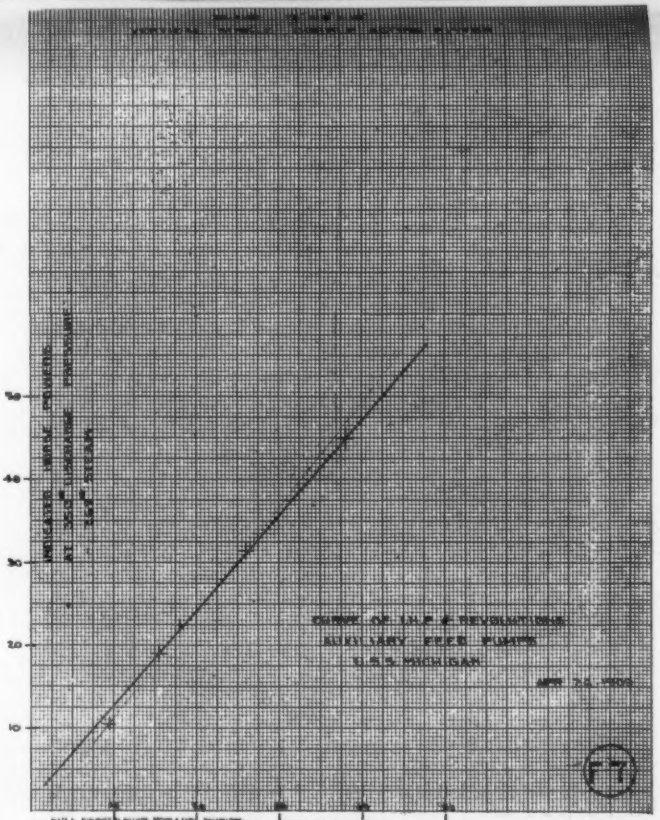

140
120
100
80
60
40
20
DOUBLE STROKES PER MINUTE
F3

REVS PER MINUTE

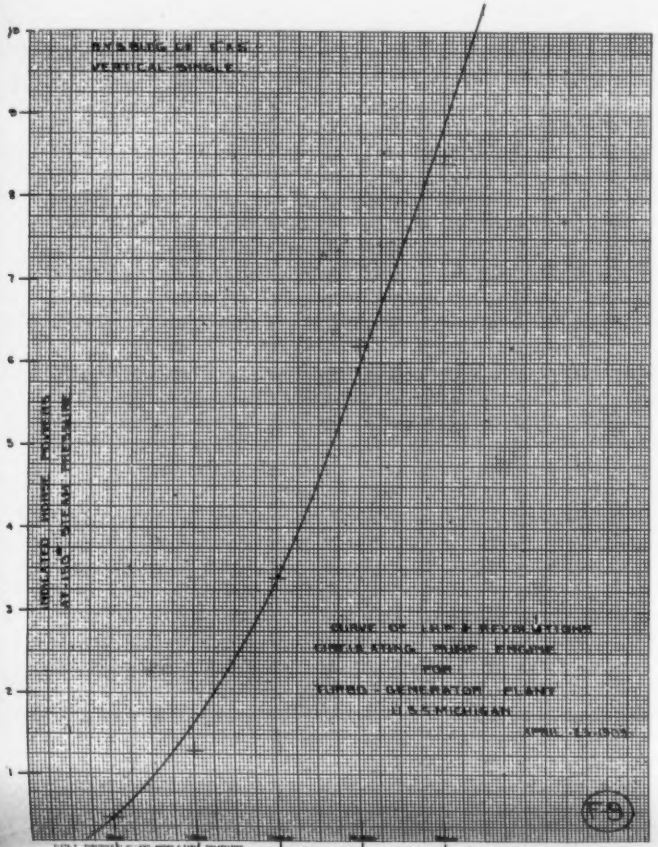
DOUBLE STROKES PER MINUTE.

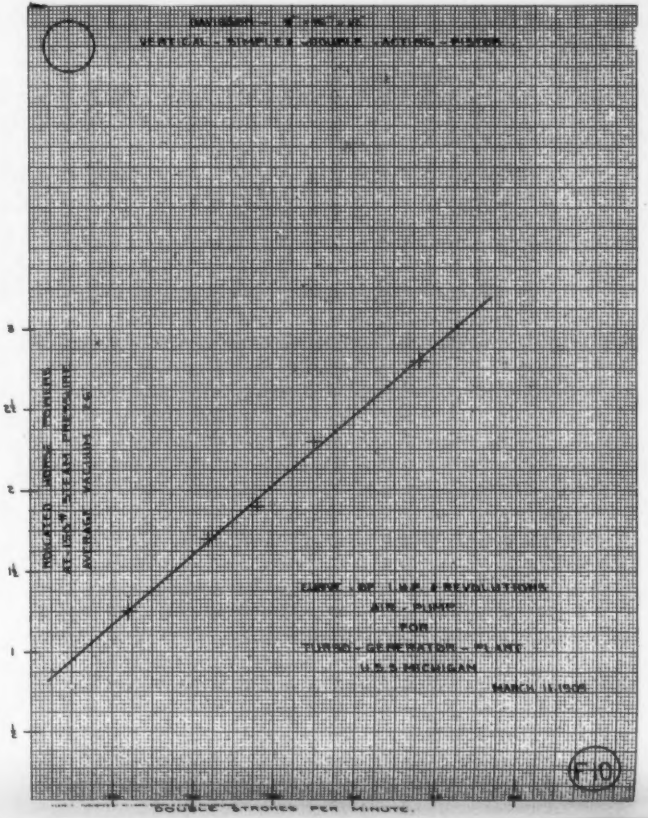


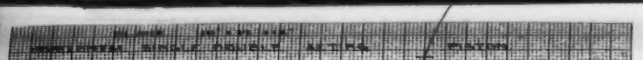
DOUBLE STROKES PER MINUTE.

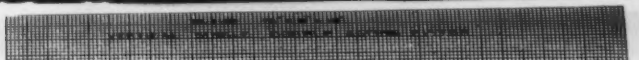


DOUBLE STROKES PER MINUTE


INDICATED HORSE POWERS
AT 100# STEAM PRESSURE
AVERAGE VACUUM 26"
REVS PER MINUTE
CURVE OF I.H.P. & REVOLUTIONS
SINGLE STAGE TURBO ENGINE
FOR
TURBO-GENERATOR PLANT
U.S.S. MICHIGAN
APRIL 13 1908
F8


VERTICAL SIMPLEX DOUBLE ACTING PISTON
INDICATED HORSE POWERS
AT 100# STEAM PRESSURE
AVERAGE VACUUM 26"
DOUBLE STROKES PER MINUTE.
CURVE OF I.H.P. & REVOLUTIONS
AIR PUMP
FOR
TURBO-GENERATOR PLANT
U.S.S. MICHIGAN
MARCH 11 1908
F10





INSPECTION AFTER TRIAL.

Summary of Findings of the Board.

With the exception of a few recommendations of minor note the Board found the machinery to be in excellent condition, there was no evidence of grease or scale in the boilers and the water surfaces appeared to be in excellent condition The brick work about the boilers, including the bridge walls, the grate and bearing bars and all furnace appliances were found to be in excellent condition. Exterior of tubes were examined as far as visible and found to be in good condition.

All main-engine and piston valves, main cylinders, high-pressure piston rings, one intermediate and one low-pressure piston rings, one high-pressure, two intermediate-pressure and two low-pressure crossheads, both high-pressure, one intermediate-pressure and one low-pressure crankpin, one main bearing of each engine, both main and auxiliary condensers, both main feed pumps and one auxiliary feed pump, both main air pumps, steam end of circulating-pump engines, steam and water cylinders of one fire and bilge pump, and all boilers, interior and exterior, except boiler C which was under steam for auxiliary purposes.

PRINCIPAL DIMENSIONS OF HULL.

Length between perpendiculars, feet and inches	450–0
on load water line (24 feet 6 inches), feet and inches	450–0
over all, feet and inches	452–09
of straight keel, feet and inches	384–06
Projection forward of F.P., feet and inches	2–09
aft of A.P., feet and inches	0–0
Breadth, extreme, at L.W.L., outside of armor, feet and inches	80–02⅜
molded, feet and inches	79–10½
Depth, molded, main deck, at side, M.S., feet and inches	34–06⅜
upper deck, at side, M.S., feet and inches	42–10 7/16
Ratio of length to beam	5.6
Displacement per inch, at L.W.L., tons of S.W	64.38
Area of midship section, square feet	1,890.0
L.W.L. plane, square feet	27,060.0
wetted surface, square feet	45,625.0

TANKS.

Capacity of Fresh-Water Tanks.

Reserve Feed-Water Tanks.

Compartment No.	Side.	Frames.	Cubic feet.	Gallons.	Tons F.W
B–94	P.	56–61	814	6,066	22.6
B–95	S.	56–61	814	6,066	22.6
B–96	P.	61–66	814	6,066	22.6
B–97	S.	61–66	814	6,066	22.6
B–98	P.	66–70	650	4,858	18.1
B–99	S.	66–70	650	4,858	18.1
Totals.....			4,556	33,980	126.6

Trimming Tanks.

Compt. No.	Side.	Frames.	Cubic feet.	Tons S.W.	Tons F.W.
A–1	P. and S.	Stem–3	705	20.1	19.5
A–2	P. and S.	3–5	1,130	32.2	31.1
D–13	P. and S.	100–103½	1,965	56.1	54 5
D–14	P. and S.	103½–Stern post.	1,300	37.1	36.1
Totals.....			5,100	145.5	141.4

Fresh-Water Tanks.

Compartment No.	Tank No.	Deck.	Side.	Frame.	Gallons.	Tons.
A–55	1	Upper plat.	S.	18–22	5,060	18.8
A–55	2	Upper plat.	P.	18–22	5,060	18.8
A–55	3	Upper plat.	S.	19–22	4,215	15.7
A–55	4	Upper plat.	P.	19–22	4,215	15.7
Reservoir	1	Boat.	S.	50–52	1,004	3.7
Reservoir	2	Boat.	S.	76–77	1,004	3.7
		Totals.....			20,558	76.4

Feed-Water and Filter Tanks.

Kind.	Location.	Side.	Gallons.
Feed.	Engine room.	P.	4,100
Filter.	Engine room.	P.	900
Feed.	Engine room.	S.	4,100
Filter.	Engine room.	S.	900
	Total.....		10,000

Small Tanks Fresh Water.

Tank.	Deck.	Side.	Frame.	Gallons.
Chief P. O. wash room.	Main.	S.	74–78	50
Laundry.	Main.	S.	2–12	200
Fireman's wash room.	Main.	C.L.	50–61	500
Servant's wash room.	Main.	S.	71–74	102
	Total.....			852

Double-Bottom Compartments.

Compartment No.	Side.	Frames.	Cubic feet.	Tons S.W.	Tons F.W.
A–94	P. and S.	11–17	2,885	82.4	80.1
A–95	P. and S.	17–22	2,256	64.4	62.6
A–96	P. and S.	22–28	2,850	81.4	79.1
A–97	P. and S.	28–32	1,951	55.7	54.1
A–98	P. and S.	32–38	2,971	84.8	82.5
A–99	P. and S.	38–43	3,818	109.0	106.0
B–85	P. and S.	43–47	3,026	86.4	84.0
B–86	P. and S.	47–52	3,765	107.5	104.5
B–87	P. and S.	52–56	2,987	85.3	82.9
B–88	P.	56–61	1,030	29.4	28.6
B–89	S.	56–61	1,030	29.4	28.6
B–90	P.	61–66	962	27.4	26.7
B–91	S.	61–66	962	27.4	26.7
B–92	P.	66–70	741	21.1	20.5
B–93	S.	66–70	741	21.1	20.5
C–97	P. and S.	70–74	2,666	76.2	74.0
C–98	P. and S.	74–78	2,544	72.6	70.6
C–99	P. and S.	78–81	1,900	54.2	52.6
D–96	P. and S.	81–84	1,880	53.7	52.2
D–97	P. and S.	84–87	1,846	52.7	51.2
D–98	P. and S.	87–93	3,720	106.2	103.3
D–99	P. and S.	93–98	2,060	58.8	57.2
Totals.....			48,591	1,387.1	1,348.5

MAIN ENGINES.

There are two main engines, right and left-handed, outboard turning when going ahead, each in a watertight compartment. They are of the vertical, direct-acting, four-cylinder, triple-expansion type, designed to develop about 16,500 I.H.P. at about 125 r.p.m., with a steam pressure of 265 pounds at the H.P. cylinder. The arrangement of cylinders, beginning forward, is forward L.P., H.P. and I.P., and after L.P. respectively; the F.L.P. and H.P. and A.L.P. and I.P. being bolted together, thus allowing freedom for expansion between the H.P. and I.P. cylinders in fore-and-aft and vertical planes, while a system of tie rods and braces prevent fore-and-aft and athwartship motion to the engines as a body. The material used for the cylinders is cast iron, fitted with close-grained, hard cast-iron piston and valve-chest liners, the $\frac{3}{4}$-inch space between the casings and piston liners being utilized as the

steam jacket, the top and bottom heads of the I.P. and L.P. cylinders also being jacketed. Steam for the jackets is taken from the boiler side of the main-engine throttle valve, and passes successively through the cylinders, spring-reducing valves at the I.P. and L.P. cylinders, allowing a maximum steam pressure of 130 and 60 pounds respectively. Each end of the piston valves is fitted with a packing ring of hard cast iron, made practically solid, being turned larger than the bore of the valve-chest liners, cut obliquely, the abutting ends bolted together and finished to fit the liners. The body of the valve is steel pipe with cast-steel heads. The H.P. valve stem is connected to the link block, and the I.P. and L.P. stems to a cast-steel crosshead which is connected to the link block, the Stephenson double-bar link motion with adjustable cut-off being used. There are six graduations for points of cut-off on each reverse-shaft arm for H.P. and I.P., and five for each L.P., and are for the ahead motion only.

The cylinders are supported by a framing consisting of twelve forged-steel columns, $5\frac{1}{2}$ inches diameter, flanged top and bottom for bolting to the cylinders and bed plate; each athwartship pair of columns being trussed by X-braces, and stiffened fore and aft by horizontal and diagonal tie rods leading from the middle pairs of columns, thus offering no resistance to cylinder expansion.

The crosshead guides, which are of cast iron for the ahead and cast steel for the backing, are bolted to the top to facings provided on the cylinders and at the bottom to cast-steel I-section strongbacks carried by the engine framing. The guides, which are of the slipper type, are hollow for the circulation of water to keep them cool.

The bed plates are of cast steel, made in three sections, flanged and securely bolted together by body-bound bolts. Each bed plate when assembled consists of two longitudinal and six cross girders of I-section, well stiffened by ribs, and furnishes the seatings for the crank-shaft bearings, engine framing and turning engine. Body-bound bolts secure the bed plates to the keelsons, forged-steel washers being fitted at each

bolt between the bed plate and the keelson, the space between the washers being filled in with yellow pine.

The crank shaft is arranged with the cranks 90 degrees apart and is in two sections, the forward L.P. and H.P. being in one, and the I.P. and after L.P. on the other, the sequence of cranks being H.P., I.P., F.L.P. and A.L.P.

The upper ends of the connecting rods are forked for the crosshead brasses; these brasses and those of the crank pin being lined with white metal. Crank shafts and connecting rods are high-grade machinery forgings. The pistons are conical shaped, rough machined all over, the material of the H.P. being cast iron, and that of the I.P. and L.P. cast steel, the followers in each case being of the same material. The pistons are bored taper to fit the rods, and have a square counterbore on the under side to suit the shoulder on the piston rods. Pistons are secured to the rods by steel nuts, locked in place by plates bolted to the piston.

The packing rings are of hard cast iron, being solid plug for the H.P. and practically solid I.P. and L.P., having been cut obliquely for machining and the ends clamped solidly together for I.P. and L.P.; lugs cast on the back of the rings limit the play, the bore being $\frac{1}{8}$ inch greater than the corresponding bore of the piston.

The piston rods are of high-grade, and the crossheads and slippers class "A" forged steel, the slippers being faced with white metal. The ends of the rods are tapered to fit the pistons and crossheads, and the slippers are bolted to the crossheads.

The reversing engine is located outboard and is bolted to the top of the H.P. cylinder. There is an oil-control cylinder of brass connected to the steam cylinder by wrought-steel stanchions which serve as crosshead guides. The reverse shaft is also on the outboard side of the engines, near the top of the engine framing, and is connected to the crosshead of the reversing engine by two forged-steel connecting rods. Differential levers control the valve motion.

The turning engine is located outboard on the main-engine bed plate, between the H.P. and I.P. cylinders. The shaft

carries a worm that engages a worm wheel carried by an inclined shaft, at the lower end of which is another worm that engages the driving worm wheel located on the crank-shaft coupling flanges. The second worm is keyed to the inclined shaft by means of a feather, but may be moved vertically to engage or disengage the worm wheel on the crank shaft. A square for a ratchet, for turning by hand, has been provided on the after end of the turning-engine shaft.

MAIN ENGINE DATA.

Cylinder Data.

	H.P.	I.P.	L.P.
Diameter, inches	32	52	72
Stroke, inches	48	48	48
Thickness of body, inches	2	$1\frac{7}{16}$	$1\frac{1}{2}$
liners, inches	$1\frac{9}{16}$	$1\frac{5}{8}$	$1\frac{9}{16}$
jacket spaces, inches	$\frac{3}{4}$	$\frac{3}{4}$	$\frac{3}{4}$
valve-chest, inches	$1\frac{1}{2}$	$1\frac{3}{8}$	$1\frac{1}{2}$
Number of piston valves	1	2	2
Diameter of piston valves, top	17	19	29
balance pistons, inches	$8\frac{1}{2}$	$7\frac{7}{8}$	$15\frac{1}{2}$
Port area through valve-chest liner, top, inches	117.13	131.8	200.8
bottom, inches	122.54	132.72	208.7
Valve travel, inches	9	10	11

Valve Data for Port Engine.

Steam lead, linear, inches, top	$\frac{29}{64}$	$\frac{5}{8}$	$1\frac{3}{16}$
bottom	$\frac{9}{16}$	$\frac{3}{4}$	$1\frac{13}{64}$
Full-gear cut-off, top, per cent	81.91	75.13	65.9
bottom, per cent	74.6	65.62	55.2
Earliest cut-off, top, per cent	54.04	48.96	43.1
bottom, per cent	43.36	38.15	32.42

General Engine Data.

Diameter of piston rods, inches	$7\frac{1}{2}$	$7\frac{1}{2}$	$7\frac{1}{2}$
axial hole, inches	$1\frac{1}{2}$	$1\frac{1}{2}$	$2\frac{1}{2}$
crosshead pins, inches	$10\frac{1}{2}$	$10\frac{1}{2}$	$10\frac{1}{2}$
Length of crosshead pins, each, inches	$10\frac{1}{2}$	$10\frac{1}{2}$	$10\frac{1}{2}$
slippers, inches	28	28	22
Width of crosshead slippers, inches	22	22	17
Length of backing surface, inches	28	28	22
Width of backing surface, each, inches	$8\frac{1}{4}$	$8\frac{1}{4}$	$6\frac{1}{2}$

	H.P.	I.P.	L.P.
Length of connecting rod, center to center, inches	96	96	96
Diameter of connecting rod, top, inches	6¾	6¾	6¾
bottom, inches	8	8	8
hole, body, inches	1½	1½	3
crosshead end, inches	1½	1½	1½
pin bolts, inches	3	3	3
Number of crosshead-pin bolts	4	4	4
Diameter of crank-pin bolts, inches	4	4	4
Number of crank-pin bolts	2	4	2
Diameter of crank pins, inches	17½	17½	17½
Length of crank pins, inches	19	19	19
Diameter of hole in crank pins, inches	10	10	F.L.P. 10

Diameter of hole in crank pins, A.L.P., inches	6
shaft, inches	8
crank shaft, inches	16¼
coupling flanges, inches	27½
Width of crank-shaft coupling flanges, inches	3¾
Number of coupling bolts, each section	8
Diameter of coupling bolts, inches	3¾
pitch circle, inches	22½
Width of crank webs, inches	18½
Thickness of crank webs, inches	10
Number of main bearings	7
Length of main bearings, H.P., inches	20¼ and 25
I.P., inches	12½ and 20½
forward L.P., inches	20½
after L. P., inches	20¼ and 12½

REVERSING ENGINES.

Diameter of steam cylinder, inches	13
oil cylinder, inches	7
steam-piston rod, inches	2⅞
oil-piston rod, inches	2⅝
Stroke, inches	21
Length of connecting rods, feet and inches	4–10½
reverse levers, inches	18
Diameter of reverse shaft, inches	7 and 6½
bearings, inches	7 and 6½
Length of reverse-shaft bearings, inches	9

TURNING ENGINE.

Number of cylinders	2
Diameter of cylinders, inches	6
Stroke, inches	7

ASSISTANT CYLINDERS.

An interesting and important feature of the propelling machinery is the Lovekin improved assistant cylinders, applied to the valve gear of the main engines, this ship being the fourth in the United States Navy to be equipped with this simple and yet most effective device for overcoming the inertia which is primarily the cause of considerable wear upon the heavy valve gear working at high speeds.

The assistant cylinders used on this vessel are designated Type E, having the chief characteristics of type A, used for the cruiser *Washington,* and can be designed to fulfill the same requirements as type D used on the *Kansas.*

This type of assistant cylinder eliminates all piping, each cylinder being dependent upon its own receiver pressure, and consequently when fitted to the L.P. valve gears they will be of a larger diameter than type D. The results were highly satisfactory, as evidenced by the lack of vibration under all working conditions.

For results obtained upon the *Kansas,* see JOURNAL, Volume XIX, No. 2, for the work done by the assistant cylinders on the port H.P. valve gear.

Interested readers will be well repaid by consulting the following references: "Balance Cylinders, Theoretically and Practically Considered," "Performance of the Assistant Cylinders of the *Washington,*" and JOURNAL OF THE AMERICAN SOCIETY OF NAVAL ENGINEERS, Volume XVI, No. 3; XVII, No. 3; XVIII, No. 3, and "The Balancing of Valve Gears," "Journal of the Society of Naval Architects and Marine Engineers," November, 1902.

SHAFTING AND THRUST BEARING.

The shafting is arranged in four sections, as follows: Thrust, line, stern-tube and propeller, all of Class A forged steel. The line and stern-tube shafts are coupled as follows: Two forged-steel collars fit on the end of the stern-tube shaft, secured to prevent turning by four keys, and into a circumferential groove between the collars near the end of

the shaft is fitted a pressure ring made in four sections, the coupling bolts passing through the steel collars and the flange on the thrust shaft. The stern-tube and propeller shafts are coupled as follows: The ends of the shafts are joined by a locking ring, over which is a long clamp in halves, each half held in place on the shafts by a longitudinal key, and the two sections of the clamp coupling secured by fitted bolts.

The bodies of the stern-tube and propeller shafts are covered with composition watertight casing, and each outboard coupling is covered with a cast and wrought-steel casing filled with melted pitch.

The thrust bearing is of the horseshoe type, with a steady bearing at each end, fitted with glands to prevent the escape of oil. The body is of cast iron, so shaped as to form an oil reservoir, and the horseshoes are of cast steel, made hollow for the oil and water service. They are faced with white metal, and have oil grooves on the bearing surface.

DATA FOR SHAFTING.

Diameter of thrust shaft, inches	15¼ and 15½
hole, inches	7½
Number of thrust-shaft collars	12
Outside diameter of thrust-shaft collars, inches	23½
Width of thrust-shaft collars, inches	2
space of thrust-shaft collars, inches	4
Length of thrust-shaft bearings, inches	18
Number of thrust shoes	12
Diameter of thrust side rods, inches	3¾
line shafting, inches	15¼
stern-tube shafting, inches	16
shaft hole, inches	8
Length of stern-tube shaft, forward bearing, inches	51
after bearing, inches	51½
Diameter of propeller shaft, inches	16
hole, inches	8
Length of strut bearing, inches	51
Diameter of thrust-shaft coupling flange, inches	27½
Thickness of thrust-shaft coupling flange, inches	3¼
Number of thrust-shaft coupling bolts	8
Diameter of thrust-shaft coupling bolts, inches	3¼
pitch circle, inches	22½
Length of collars on stern-tube shaft, inches	2¼ and 10
Diameter of collars on stern-tube shaft (inside), inches	16

Number of keys	4
Length of keys, inches	12
Width of keys, inches	2¼
Depth of keys, inches	1¼
Thickness of pressure ring, inches	1 and 1
Inside diameter of pressure ring, inches	14¼
Length of outboard coupling clamp, inches	51
Outside diameter of outboard coupling sleeve, inches	21½
Width of longitudinal keys, inches	2¼
Depth of longitudinal keys, inches	1¼
Width of locking ring, inches	4
Outside diameter of locking ring, inches	16
Number of bolts	16
Diameter of bolts, inches	2
Length of crank shaft, feet and inches, each	32–00½
thrust shaft, feet and inches, each	14–02
line shaft, feet and inches, each	24–09
stern-tube shaft, feet and inches, each	43–00½
propeller shaft, feet and inches, each	31–04¾
Total length of all shafting, feet and inches	145–04¾

PROPELLERS.

The hub is fitted on the tapered end of the propeller shaft and held in place by one longitudinal key and a composition nut on the end of the shaft, the nut being threaded the reverse of the direction of the propeller. The nut is locked in place and covered with a composition cap bolted watertight to the hub. The blades fit into tapered recesses in the hub, being held in place by rolled manganese tap bolts, composition chocks being fitted around the bodies of the bolts to keep the blades from shifting after being set to the desired pitch. The bolt holes in the hub are oval in shape and allow a pitch adjustment of 9 inches either way. The material for blades and hubs is manganese-bronze. The driving faces of the blades were machined to a true screw by a machine especially designed for this purpose, the backing face being machined where possible and the balance of the surface ground and polished. Each propeller was accurately balanced.

DATA FOR ONE PROPELLER.

Number of blades	3
Diameter of propeller, feet and inches	17–06½
Pitch for official trial, feet and inches	18–00

Pitch, maximum, feet and inches	18–09
minimum, feet and inches	17–03
Ratio of pitch to diameter	1.025
Helicoidal area, square feet	88.5
Projected area, square feet	75.28
Disk area, square feet	241.67
Ratio projected to disk area	.311
Area of immersed midship section, square feet	1,890.0
Ratio disk to immersed midship-section area	.255
projected to immersed midship-section area	.085
Number of tap bolts for blades	27
Diameter of tap bolts for blades, inches	3½
Length of tap bolts for blades under head, inches	6½
Width of longitudinal key, inches	3½
Thickness of longitudinal key, inches	2¼
Length of longitudinal key, inches	35
Diameter of shaft-nut thread, inches	11
Length of shaft-nut thread, inches	9
Number of threads per inch	4
Immersion of tip of blade, inches	78½
Tip of blade above keel, inches	4½

DATA FROM OFFICIAL FOUR-HOUR TRIAL.

	Starboard.	*Port.*
Average revolutions per minute on course	119.43	119.49
Slip, per cent. of its own speed	11.48	11.44

WEIGHTS OF PROPELLING MACHINERY.

The contract weight of the propelling machinery and auxiliaries was 1,550 tons, the actual weight being 1,555.308 tons, or 4.854 tons overweight. Below will be found the weights in detail and the sum total. (Weights subject to final correction.):

	Pounds.
Cylinders of main engines	323,873
Shafting	203,710
Main-engine framing and bearings	220,553
Reciprocating parts of main engines	81,683
Main-engine valve gear	65,750
Main condensers	89,724
Main, air and circulating pumps	41,926
Propellers	52,776
Boilers	799,307
Boiler fittings	346,692

	Pounds.
Smoke pipes and uptakes	259,341
Steam and exhaust piping and valves	100,704
Suction and discharge piping and valves	75,875
Lagging and clothing	14,981
Flooring, gratings, etc	81,186
Auxiliaries	127,761
Fittings and gear	88,177
Water	233,923
Stores, tools and spare parts	82,976
Miscellaneous machinery	183,059
Total	3,483,890
Total weight as above, in tons	1,555.308
Less:	
Contract weight, tons 1,550.000	
Authorized changes, tons .454	
	1,550.454
Net weight, excess of contract weight, tons	4.854

BOILERS.

The boilers on this ship are of the Babcock & Wilcox superheater type, and were designed, built and installed by this well-known concern. The battery consists of twelve boilers placed four each in three watertight compartments, all compartments being symmetrically arranged.

Each boiler has one drum extending the full width of the boiler and is located within the casings, so that about one-fourth of the shell is in contact with the gases at the top of the combustion chamber. Immediately below the drum are the front headers, and at the back of the boilers are the back headers, connected by tubes set at an angle of 15 degrees.

The weight of the drum and front headers, etc., is carried by the furnace front, and that of the back headers by a light structural steel girder that also forms a portion of the casing.

This is protected from the fire by a bridge wall of brick extending the full width of the furnaces. There are two of these, of equal size, separated by a wall of rectangular water legs that extend from the lower row of tubes to a point just below the surface of the grate. The side walls are similarly constructed, and all are connected to a mud drum carried in the boiler front immediately below and connected to the front headers, thereby providing a constant circulation of water and affording excellent means for draining and blowing off.

The boiler casings are made of steel plates and shapes, fire brick and block magnesia being used for insulation. Front and back at the header space they are in the form of doors of such size that they may be easily removed for access to the inside of the tubes, and the sides are removable in sections for access to the baffle plates and for cleaning soot from the tubes.

Each furnace is provided with two furnace and two ash-pit doors, and the grate bars are of the ordinary common type, of such size and shape as to be handled by one man.

Boiler Drums.—The boiler drums are of open-hearth steel plate, having two seams which are butt strapped inside and out. The heads are convex, the radius of which is equal to the inside diameter of the drums, and in each is a flanged manhole shaped from the same plate. All butt straps were formed to the proper curvature of the drum under hydraulic pressure, the rivet holes being punched about ¼-inch smaller than the diameter of the rivets used, and then drilled out full size after the plates were rolled and assembled. After drilling, all burrs were cleaned off, the plates reassembled, with turned bolts holding the parts in place for riveting. Wrought-steel pads securely riveted to the drum shell are provided for attaching all valves and fittings.

The superheaters also are of the regular Babcock & Wilcox design, but the *Michigan* is the first of the new vessels in which they have been fitted; they are placed on top of the boilers at the rear, the baffle in the first pass of the boiler being extended up to the superheater, thereby compelling the gases of

combustion to pass over the superheater tubes before entering the second pass across the boiler tubes. This insures a much higher efficiency of superheating surface than would be the case if the superheater was so located that only the gases that had passed entirely through the boiler were available for superheating.

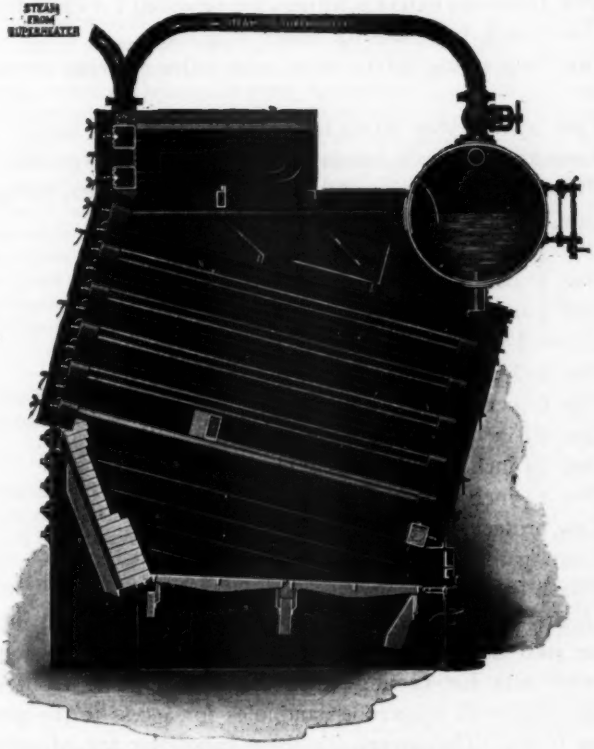


Fig. 3.—B. & W. Boiler with Superheater.

The superheater is composed of U-shaped seamless-steel tubes, two inches outside diameter expanded at their ends into open-hearth forged-steel boxes. Opposite each group of four tube ends is placed a handhole, which is closed by a fitting uniform in size and design with those used on the

boiler. All parts of the superheater are accessible for cleaning and repair.

The design and location of the superheater are plainly shown in the engraving, Fig. 3.

The performance of the boilers was most satisfactory in every respect.

The following external fittings are provided for each drum:

One 5-inch hand-closing boiler stop valve.

One twin-spring safety valve, each valve 5 inches in diameter.

Two 2½-inch stop valves for main and auxiliary feed.

Two 2½-inch check valves for main and auxiliary feed.

Two Klinger reflex water gauges with automatic fittings.

One 1½-inch surface blow valve.

One ½-inch sentinel valve.

One ½-inch air valve.

One ¼-inch steam-gauge connection.

Three ⅜-inch try cocks.

The following internal fittings are provided:

One 6-inch brass dry pipe.

One 2½-inch main-feed pipe.

One 2½-inch auxiliary-feed pipe.

One 1½-inch pipe and scum pan for surface blow.

Zinc protectors and baskets.

Scum pan.

Swash baffles.

Headers.—The headers are of forged steel, forged in one piece into a rectangular section, having male and female sinuous side for nesting when assembled. The front side is provided with numerous handholes for access to the generating tubes. The covers for these handholes are of pressed steel, held in place by one stud, nut and dog. All holes for the generating tubes anl connecting nipples between headers and drums are bored and reamed the size of tubing used.

Tubes.—The generating tubes are straight, and those in the superheater box have one U-bend, and made of seamless cold-drawn steel. These and the header and drum nipples, which

are of the same material, are rolled in place by the Babcock & Wilcox patent expander. Steam generated can be passed directly in a saturated state, or all passed through the superheater as may be desired.

DATA FOR BOILERS.

Number of boilers	12
Length of drum, feet and inches	14–10½
Inside diameter of drum, inches	42
Thickness of drum plate, inch	1 1/16
Number of headers, each boiler	24
Heating surface per header and tubes, square feet	147.6
Total heating surface for one boiler, square feet	3,541.7
grate surface for one boiler, square feet	87.35
heating surface for all boilers, square feet	42,500
superheater for all boilers, square feet	4,720
Number of boilers per smoke pipe	6
Height of smoke pipe above grate, feet and inches	91–11½
Area through smoke pipe, square feet	77.24
Ratio grate surface to smoke-pipe area	6.786
Size of generating tubes, inches	2 and 4
Thickness of 2-inch generating tubes, B.W.G.	8.0
2-inch superheater tubes, B.W.G.	8.0
4-inch generating tubes, B.W.G.	6.0
Exposed length of generating tubes, feet and inches	9–0
Number of 2-inch generating tubes per boiler	611
2-inch superheater tubes per boiler	92
4-inch generating tubes per boiler	130
Inclination of tubes, degrees	15.0
Height of boiler, feet and inches	13–05
Length of boiler, feet and inches	13–06
Width of boiler, feet and inches	14–03½
Weight of one boiler, complete, dry, pounds	83,887
water in one boiler, at middle cock, 58° F., pounds	14,072
one boiler complete, wet, pounds	97,909
one boiler complete, full, wet, pounds	103,809
Total weight of boilers, dry, pounds	1,006,644
water in boilers, pounds	168,864
boilers, wet, pounds	1,175,628
Designed working pressure, pounds per square inch	295
Test pressure, pounds per square inch	450

MAIN AND AUXILIARY STEAM LINES.

The main steam pipes are arranged symmetrically in two systems, outboard, port and starboard, through the firerooms with a 7-inch cross connection at the forward end of the for-

ward fireroom, and a 6-inch cross connection at the forward end of the engine rooms, thus completing a loop forward of the main engines. Abaft of the steam drum on the after boilers the steam lines pass over to the inboard side and through the forward athwartship bulkhead to the separators at the forward inboard end of each engine room and from these directly to the main-engine throttle valves, through the medium of one length of pipe and an elbow constituting a long slip joint.

The main steam pipes are supplied from each boiler drum and superheater by 5-inch pipe, the valves and connections being so arranged that the steam may be sent either through the superheater or direct, as desired. Forward of the forward boilers, in the middle boiler compartment, the size of the lines are 7-inch; for the after boilers in this compartment to the forward boilers in the after compartment the size is 10 inches, and for the after boilers to the main steam separators it is 12 inches, from which to the main engine 11-inch is used.

Steam to dynamo engines is taken, port and starboard, from the cross connection in the forward boiler compartment, and for forward auxiliaries, heating system, galleys, whistle and siren from a casting through the necessary reducing valves on the port side. Steam for all auxiliaries in each compartment is taken from a casting on the main line; and in each engine room steam for auxiliaries (6½-inch), receivers (5-inch) and bleeder (4-inch), is taken from the head casting of the main steam separator. The main steam stop valves at each separator and the auxiliary cross connection between the engine rooms may be operated from the deck above.

For the 5-inch diameter pipes expansion is taken care of by liberal bends, but for all sizes above this the pipes are in straight leads carrying the usual standard sleeve expansion joint. Owing to the use of superheated steam the entire line is of steel, the pipe being seamless drawn, with flanges of wrought steel, rolled and expanded on by the Lovekin patent expanding and flanging machine. These pipes withstood a hydrostatic test pressure of 600 pounds per square inch without showing any evidence of leak. The valves, fittings and ex-

pansion joints are of Class B cast steel, with Monel metal seats and bushings, and metallic packing for valve stems and gland stuffing boxes; all joints being scraped to a true surface, and made up metal to metal.

The auxiliary steam line in the engine rooms is taken as noted above, and forms a loop of both engine rooms through the medium of a cross-connection aft. From this line steam to the steering engine is supplied by a 4½-inch branch on the starboard side. The distributing castings in the engine rooms also supply steam to main feed pumps, main air pumps, main circulating-pump engines, engine-room fire and bilge pumps, distiller circulating pumps, auxiliary air and circulating pumps, fresh-water pumps, oil pumps, turning and reversing engines, cylinder jackets, after heating system and galley, and connections for blowing out sea chests and boiling out condensers, feed-water heaters and grease extractors.

MAIN CONDENSERS.

There is one main condenser in each engine room. They are 6 feet 9 inches in diameter by 15 feet 3 inches long by 13 feet between tube sheets. The shell plating is of steel, the water chests of composition, tubes of composition—70 parts copper, 29 zinc, 1 tin; tube sheets of rolled Muntz metal, and the tube-supporting plates of sheet steel bushed with composition.

The forward water chest, being the one for the entrance and exit of the circulating water, has a division plate on the center line of the condenser. Sizes of inlet and outlet are 18½ inches in diameter, the inlet nozzle being on the bottom. There are two exhaust nozzles, each 28 inches diameter.

AUXILIARY CONDENSER.

There is one horizontal combined air and circulating pump with surface condenser in each engine room.

PUMPS AND AUXILIARY ENGINES.

Auxiliary.	Number.	Type and make.	Steam cylinders.				Water cylinders.			
			Number.	Diameter, inches.	Diameter piston rod, inches.	Stroke, inches.	Number.	Diameter, inches.	Diameter piston rod, inches.	Stroke, inches.
Main air pumps	2	Blake, twin, vertical beam	2	12	2	18	2	30	2¾	18
Main circulating pumps	2	N. Y. Ship Bldg. Co., vertical comp. engine, centrifugal pump	1 H.P.	20	2½	20	1	56½ im	18½ in	...
			1 L.P.	30	2½	20	1	56½ im	18½ o	...
Main feed pumps	2	Blake vertical, Simplex, piston	1	18½	3½	18	1	13	3½	18
Auxiliary feed pumps	3	Blake vertical, Simplex, piston	1	12	2½	18	1	8	2½	18
Hotwell pumps, dynamo	2	Davidson vertical, Simplex, piston	1	4½	¾	6	1	5	¾	6
Fire and bilge pumps, eng. room	2	Blake vertical, Simplex, piston	1	12	2½	18	1	10	2½	18
fireroom	3	Blake vertical, Simplex, piston	1	12	2½	18	1	10	2½	18
Shaft and bilge pumps	2	Plunger, single-acting	...	...	...	...	1	8	...	8
Auxiliary condenser pumps	2	Blake horizontal, Simplex, combined air and circulating	1	6	1½	12	1a	10	1½	12
							1w	10		
Dynamo condenser pumps, air	2	Davidson vertical, Simplex, double-acting, piston	1	8	1½	12	1	16	1½	12
circ'g	2	N. Y. Ship Bldg. Co., vertical, single engine, centrifugal pump	1	5	1½	5	1	30	7in	...
									7o	
Evaporating and distilling plant	1	Fresh-water, Blake vertical, Simplex, piston	1	4½	⅝	6	1	5	⅝	6
	2	Distiller, circulating, Blake horizontal, Simplex, piston	1	10	1¾	14	1	12	1¾	14
	1	Evaporator feed, Blake vertical, Simplex, piston	1	4½	⅝	6	1	5	⅝	6
Ice machine	2	2-ton Allen dense-air, with return air cooler	1	9½	1½	13	1c	7	1½	13
							1e	5½		
Engine-room oil pump	2	Blake horizontal, duplex, piston	2	2	¼	2½	2	1½	¼	2½
Dynamo oil-cooling pump	1	Davidson horizontal, Simplex, piston	1	3½	¾	6	1	3½	¾	6
Air compressors	4	Westinghouse vertical	1	11	1¾	12	1c	11	1¾	12
Dynamo turbines	4	Horizontal Curtis 2-stage turbines, connected to double-ended generators, C. C. 4-pole, 200 kw., 1,700 r.p.m., 125 volts.								
Forced-draft blowers	12	Motor-driven Sirocco fan, air inlet (a) 23½ inches diam., fan 31 inches diam. G. E. Co. motors, 6 to 22 H.P., 650 to 1,050 r.p.m., 125 volts, capacity, 17,500 cubic feet. Maximum air pressure, 2½ inches.								

a, air. *w*, water. *c*, compressor. *e*, expander. *i*, impeller. *in*, inlet. *o*, outlet.

PUMPS AND CONNECTIONS.

Pumps.	Suction pipes from—		Discharge pipes to—		Location.
	Ins.		*Ins.*		
Main air	11	Condenser.	9½	Main feed tanks.	One in each engine room.
Main circulating	18½	Sea.	18½	Condenser.	One in each engine room.
	15½	Main drain.	18½	Overboard	
Main feed	7	Feed-tank connecting pipe.	5½	Main feed discharge main.	One in each engine room.
	5½	Channel ways.	5½	Auxiliary feed suction main.	
Auxiliary feed	3	Bottom blows.	3½	Auxiliary feed main.	One in each boiler room.
	3½	*C. & R. pipes from ship's side.	3½	*Main feed tank.	
	4	Feed suction pipe.	3½	*Reserve-feed water tanks.	
	3½	*Reserve-feed water tanks.	3	Overboard.	
	1½	Hose connection.	2½	Hose connection.	
Fireroom fire and bilge	5	Fireroom floors.	5	Fire main.	One in each boiler room.
	5	Sea.	5	Overboard in same compartment.	
	5	C & R. drainage manifold.	2½	Hose connection.	
	1½	Hose connection.			
Fire and bilge	5	Sea.	5	Fire main.	One in each engine room.
	5	Engine-room bilge.	5	Overboard.	
	5	Crank pits.	2½	Hose connection.	
	4½	Shaft alley.			
	5	C. & R. drainage manifolds.			
	1½	Hose connection.			
Shaft bilge	4½	Engine-room bilges.	4½	Overboard.	One in each engine room.
	4½	Crank pits in same compartment.			
	4½	Shaft alley.			
Distiller circulating	5	Sea.	5	Distillers.	Protective deck under evaporators.
			4	Sanitary system.	
			4	Fire main.	
Auxiliary air and circulating	5½	Auxiliary condenser.	3½	Main feed tank.	One in each engine room.
	5½	Sea.	5½	Overboard.	
Dynamo air	5	Dynamo condenser.	5	Hotwell tank.	In dynamo room.
Dynamo circulating	7	Sea.	7	Overboard.	In dynamo room.
Evaporator feed	2	Sea.	2	Evaporators.	Near evaporators.
	2	Distiller circulating-water discharge.			
Distiller fresh water	2	Bottom of distillers.	2	Fresh-water tanks.	In evaporator room.
			2	Main feed tanks.	
			2	Reserve-feed water tanks.	
Engine-room oil	1	Oil-storage tanks.	1	Distributing tank, or 20-gallon tanks, with overflow pipe from tank to pump suction.	One in each engine room.
Hotwell	3	Hotwell tanks.	2½	Feed suction pipe No. 1 fireroom.	One in each dynamo condenser room.
			3	By-pass to auxiliary feed pump discharge to main feed tanks.	

Connections marked * are on the after pump only.

DATA FOR ONE CONDENSER.

Number of tubes	4,466
B.W.G. of tubes	16
Outside diameter of tubes, inch	$\frac{5}{8}$
Spacing of tubes, inch	1
Length of tubes between tube sheets, feet and inches	13–0
Number of supporting plates	1
Cooling surface, measured on outside of tubes, square feet	9,499.7
Ratio of cooling surface to total heating surface	.402
Cooling surface of condenser, square feet	553
Number of tubes	494
Outside diameter of tubes, inch	$\frac{5}{8}$
Spacing of tubes, inch	1
Length of tubes between tube sheets, inches	82
B.W.G. of tubes	16

MAIN AND AUXILIARY FEED SYSTEMS.

Feed Suction Pipes.—The main feed tanks in each engine room are connected by a 7-inch pipe, with a valve at the center-line bulkhead, from which on each side, with valves at the pipe, a 7-inch pipe leads to the main feed pump at the forward inboard end of each engine room, these pump suction pipes also being cross-connected, thus forming a loop. From the suction pipe in the port engine room a $6\frac{1}{2}$-inch pipe leads to the auxiliary feed pump in the after fireroom, from which to the middle fireroom it is $5\frac{1}{2}$ inches, the last reduction being to 4 inches for the forward pump.

Feed Discharge Pipes.—From the pumps in each engine room a $5\frac{1}{2}$-inch pipe discharges through a Navy standard grease extractor, the discharge from this connecting to and by-passing the feed-water heater, after which they unite into a common $7\frac{1}{2}$-inch pipe leading to the after set of boilers, reducing to $6\frac{1}{2}$ inches for the middle boilers and 5 inches for the forward set, the branches for each pair of boilers being $3\frac{1}{2}$ inches, reduced to $2\frac{1}{2}$ inches for each boiler. The auxiliary feed-discharge pipes being $3\frac{1}{2}$ inches for each pump, reduced to $2\frac{1}{2}$ inches for each boiler, both main and auxiliary feed connections at the boilers being provided with globe stop valves and screw-down check valves, the latter operated from the fireroom floor. All pipes are copper, seamless drawn, with

composition flanges, fittings and valves, except the 5-inch, 5½-inch, 6½-inch and 7½-inch discharge pipes, which are seamless-drawn steel with steel flanges. Discharge pipes were all subjected to 450 pounds hydrostatic test.

[NOTE.—In addition to the above the auxiliary feed pumps are to be arranged so that they can each discharge into the main feed line.]

EVAPORATING AND DISTILLING PLANT.

The evaporating room is located amidships at the main-deck level, between the engine-room hatches, the distillers being on the forward athwartship bulkhead of the engine hatch above the superstructure deck, and the distiller circulating pumps, at this frame port and starboard, on the protective deck.

The plant consists of four evaporators and four distillers, the designed capacity being 16,500 gallons of potable water in twenty-four hours.

The evaporator shells and heads are of steel plate, the steam-coil heads being of composition, with the brass evaporating tubes arranged in pairs with return bends at the back end, and rolled into Muntz metal tube sheets at the front end carried by the steam head.

Each evaporator is provided with steam gauges and relief valves for the shell and coils, also water columns, gauge cocks and blow-off valves.

The distillers are vertical and of the Bureau type. The shell is of cast iron, the covers and tube sheets of composition and tubes of brass, tinned inside and out. The tubes are expanded into tube sheets by rolling, expansion is taken care of by having the bottom tube sheet made with a flange that works in a stuffing box. The circulating water enters at the bottom, passes through the tubes and is discharged at the top; the vapor enters the shell at a point close to the top tube sheet, the water leaving at a similar point near the bottom tube sheet. Baffle plates are provided for the inlet nozzles for the circulating water and vapor.

Piping.—Steam for the evaporators and pumps is taken

from a reducing valve located in the starboard engine room from a branch on the auxiliary steam line. The vapor may be sent to the distillers or the auxiliary exhaust line, the evaporators being arranged for operation in single effect. The fresh water from the distillers passes through a small reservoir tank located in the evaporator room, from which it may drain by gravity to the main and reserve-feed tanks or may be pumped into these tanks or the fresh-water tanks. The distiller circulating pumps have an independent connection to the sea, and, in addition to discharging to the distillers, may discharge to the sanitary system or fire main.

A four-hour test of the entire plant was made when the ship was at sea on June 6th, 1909. The discharge from the distillers was run into the reservoir tank, and a careful record kept of the full tanks. The water was tested for purity at frequent intervals with a solution of nitrate of silver, the concentration of water in the evaporators and all conditions recorded every half hour.

The following are the averages of the data obtained from the test of entire plant:

Steam pressure in evaporator coils, pounds	24.7
shells, pounds	13.4
at reducing valve, pounds	100.0
Pump strokes per minute for entire plant:	
Evaporator feed pump	27.7
Distiller circulating pump, starboard	8.8
port	53.3
Output of distilled water in 4 hours, gallons	3,599.75
Capacity of distilled water in 24 hours, gallons	21,598.5

DATA FOR ONE EVAPORATOR.

Heating surface, tubes only, square feet	210.0
Gallons of water evaporated per square foot of heating surface in 24 hours	25.6

DATA FOR ONE DISTILLER.

Cooling surface, tubes only, square feet	83.0
Gallons of water distilled per square foot of cooling surface in 24 hours	65.4
in 24 hours	5,399.0

Temperature of sea water, degrees Fahrenheit	57.4
fresh water, discharge from distillers, degrees Fahrenheit	110.0
external air, degrees Fahrenheit	63.3
evaporator room, degrees Fahrenheit	104.4
Concentration of water in evaporators by hydrometer test, degrees Fahrenheit	$.0\frac{2}{32}$
Quality of water distilled	Fair
Height of water in evaporators above bottom of glass, inches	1.2

TURBO-GENERATING INSTALLATION.

In the dynamo room of the U. S. Battleship *Michigan* are located four direct-current turbo-generating units. They are of the horizontal Curtis type, and were built by the General Electric Company.

Each unit consists of a 200-kw., 2-stage, 1,700 r.p.m. turbine and a direct-connected 200-kw., 125-volt, 4-pole, direct-current generator.

The turbine is designed to have two stages: *i.e.*, the steam has two successive stages of expansion. This is accomplished by dividing the casing by means of a diaphragm into two compartments; each compartment containing a separate set of wheels mounted on a common shaft. The difference in pressure on the two sides of the diaphragm maintain a steamtight joint. Each set of wheels has three rows of buckets on its periphery. Between each two rows of revolving buckets there is a row of intermediate stationary buckets bolted to the casing. The revolving parts of both turbines and generators are assembled on a single-piece shaft without coupling and are supported by two bearings.

The steam passes into the valve chest through the controlling valves to the first-stage nozzles. As it flows through the nozzles, which are expanding, its velocity becomes very high, while the pressure falls correspondingly. At this high velocity it strikes the first row of buckets on the first-stage wheel, where its direction of flow is changed by the curved buckets and its velocity partially absorbed. It then flows through the intermediate stationary blades where its direction is again changed and strikes the second row of buckets on the wheel. This is

repeated on the second row of stationary blades and the third row of wheel buckets. The steam then emerges at a very low velocity and at the pressure of the first stage. This cycle is repeated in the second stage.

The wheel casing or body of the turbine is cylindrical in form, and all the radiating surface is neatly lagged with Russia iron. The casing is supported on a bed plate which is common to both the generator and turbine.

The wheel, or rotating buckets, are cut out of solid steel arranged in segments. These segments are riveted to the wheel disc, and are so designed as to size, radius and number as to make a perfect wheel.

For protecting the buckets a steel band is riveted over the outer end, the riveting being done by means of upsetting the end of the bucket.

The wheel disc is riveted to the hub, which is keyed to the turbine shaft.

The turbine shaft is made of nickel-steel and is designed sufficiently rigid to withstand any tendency to whip which might be caused by excessive water getting into the turbine.

The intermediates or stationary buckets mentioned above are made of composition metal. Over the inner end of the bucket is riveted, by upsetting the end of the buckets, a steel band for protection. The intermediates extend around the periphery only a sufficient distance to serve in diverting the steam from the nozzles. For instance, in the first stage the nozzles cover an arc of about one-eighth of the circumference of the steel, and the intermediate buckets cover an arc but slightly longer than the arc of the nozzle.

The total clearance in the axial direction between the wheel buckets and intermediate buckets is sixty-five thousandths of an inch. In a radial direction the clearance is several inches. there being no limit theoretically to this clearance. This large clearance is employed so as to take care of any excessive amount of water which may accumulate in the turbine casing. Besides, there is a large drain box so arranged under the turbine as to drain the water from each and all stages.

For successful operation on high-speed apparatus, such as turbines, a good oiling system is necessary. The oiling system for the above turbo-generating set is self-contained and is arranged as follows:

On the generator end of the shaft is a small worm gear which operates at a moderate speed a small reciprocating oil pump of sufficient capacity to supply oil under pressure to all the bearings. It also supplies oil for operating the hydraulic gear. The pressure can be varied by means of a relief valve, but is generally maintained at about ten pounds per square inch. The oil is pumped from a small reservoir, located in the turbine base, through the bearings, returning through long pipes running the length of the base. The oil in the return pipes is cooled by means of water pipes. By the arrangement the oil is always kept cool, and may be used over and over for weeks without being changed.

The controlling governor is of the centrifugal type, and is located at the generator end of the shaft. By means of levers and rods the governor is connected to the hydraulic pilot cylinder, which in turn rotates a cam shaft. Cams mounted on the cam shaft operate successively the valves admitting steam to the various nozzles.

The system of hydraulic operation of the valves is the same as used on all large turbines made by the General Electric Company.

The generator end of this unit consists of one armature core on which are two distinct and separate windings, each connected to its own commutator. The commutators are of standard shrink-ring turbine construction, the bars being mounted on a heavy cast-iron shell, this shell mounted directly on the shaft. The shaft is drilled through the center from one end with about a 3-inch hole, which latter furnishes air for the center of the armature core, where are located the ventilating ducts extending out radially through the punchings. Air, which is supplied from the ship's ventilating system, is directed through the base and thrown directly against the surface of the

commutators. This construction admits of using commutators of very moderate size.

Each winding of the armature has a normal capacity of 800 ampères at 125 volts. The two windings are operated in multiple, delivering 1,600 ampères at 125 volts.

There is one series field for compounding, and a commutating field, both of which are wired in series with the main 1,600-ampère load, so that even if slight unbalancing between the two armatures does occur there is proper compounding and compensation effected respectively by the series field and commutating field.

Each commutator is fitted with 11 brushes per stud, 4 studs, and there is mounted on the generator a galvanometer for the purpose of indicating to the attendant whether or not the commutators are dividing the load equally. If the brushes are properly set in the neutral of each commutator and the commutators are kept clean by occasional wiping with a canvas swab, the load will divide practically in halves between the commutators.

The dynamo switchboard is located in a compartment on the upper platform above the dynamo room and connected electrically with the forward distribution switchboard. The dynamo switchboard controls all four turbo-generators. An additional distribution switchboard is located aft, which, together with the forward distribution switchboard, provides current to all lighting and power apparatus.

Steam is taken from the main steam line in forward boiler compartment, and there is a steam separator, port and starboard, in the dynamo room, which drains to a trap and the steam end of the air pump. The exhaust is into either the dynamo condenser or to the atmosphere. The air-pump discharge is to independent hotwell tanks, drained by an independent hotwell pump, discharging to the auxiliary feed-pump suction main.

The condensing plant consists of one independent air pump, one centrifugal pump and engine, one surface condenser, one hotwell tank and pump, in separate compartments, port and

starboard, of the dynamo room. The sizes and pump connections are as noted in table of pumps. Each condenser has 1,600 square feet of cooling surface, sizes and lengths same as the auxiliary condenser.

The lighting system comprises a total allotment of 1,500 electric fixtures, not including special outlets for signal lanterns, truck lights, Ardois signal sets and outlets for special fixtures. There are two arc lamps in each of the engine rooms and firerooms.

There are eight 36-inch searchlights, variously disposed on the superstructure. Separate and distinct from the lighting system is the power system, which supplies energy to all auxiliary machinery run by electric motors.

A complete system of wireless telegraphy is installed. Besides the lighting and power system there is an interior communication system, which includes call bells, general alarms, shrill whistles, fire alarms, voice tubes, telegraphs and indicators.

A system of mechanical telegraphs is also installed for communication between the bridge and engine room.

VENTILATION SYSTEM.

The hull-ventilation systems are fitted complete; the fans, delivering, combined, 111,200 cubic feet of air per minute. Artificial ventilation has been provided for quarters, living spaces, magazines, turrets, turret trainers' station, storerooms, passages, air casings adjacent to bulkheads and decks, engine rooms, dynamo room, dynamo condenser room, central station, waterclosets, washrooms, staterooms, around engine hatch and other enclosures where necessary to properly ventilate or insulate compartments.

All ducts, hangers, dampers, terminals, wire mesh, cowls, operating gear and other fittings necessary to provide for efficient ventilation and to preserve the watertight subdivision of the vessel have been fitted complete in all respects.

The ducts have been designed in accordance with the Bureau's latest instructions to pass the number of cubic feet of air per minute through each terminal, as required, with the

fan running at such speed of revolution that the actual pressure of the moving air in the duct at the fan outlet is approximately five pounds per square foot. The delivery of each system and the pressure, where practicable, have been measured with fans in operation by the methods and apparatus used for fan testing by the Bureau of Construction and Repair. The ducts being so designed and constructed as to permit attachment of necessary apparatus.

The air is renewed in the various spaces approximately as follows, based on the gross capacity of the compartments and on the above pressure:

Officers' quarters and crews' space, berth deck, outside of armor bulkheads, in from ten to twelve minutes.

Officers' quarters and crews' space, berth deck, inside of armored bulkheads, in from four to six minutes.

Sick-bay quarters in about eight minutes.

Watercloset spaces in about four minutes.

Storerooms in about eight to twelve minutes.

Magazines in from six to eight minutes.

Engine rooms in about two minutes.

Steering compartments in about three minutes.

General workshop in about four minutes.

Dynamo room in about three-fourths of a minute.

Dynamo-condenser room in about six minutes.

Switch and distributing-board rooms and central station in about six minutes.

The velocity of the air through terminals in quarters and living spaces is 1,000 feet per minute, sick-bay quarters 500 feet per minute, other spaces about 1,500 feet per minute, except central station, which is about 800 feet per minute.

The fans and mains, except for engine rooms, are located above the protective deck and watertight branches lead to compartments below. No ducts have been carried through the transverse slopes of the protective deck. All watertight ducts are of galvanized steel tubing about $\frac{1}{8}$ inch thick. Natural exhaust ducts of the material mentioned above have been fitted to magazines and shell rooms. The upper end of these ducts

are carried up close to the main deck and inside of the barbettes, where practicable, and terminated with a goose neck, bell-mouthed, covered with No. 15 B. W. G. National Fabric expanded metal 1½-inch mesh; the lower ends have bell mouths covered with the same mesh.

The ammunition hoists have suitable openings cut in the hoist trunk under the upper deck and covered with No. 15 B. W. G. National Fabric expanded metal, 1½-inch mesh, used for natural exhaust from the ammunition-handling passages on the upper platform.

For ventilating the engine rooms the blowers are located below the protective deck. Branches are led from the mains to all working stations, platforms, air casing and corners of the rooms and elsewhere as required for efficient ventilation.

For ventilating the dynamo room the commutators of the dynamos are cooled by a supply of air from the ship's ventilation fans. There has been 2,000 cubic feet of air per minute delivered to each generator, and sufficient air in excess of this has been provided to change the air in the dynamo room in about two minutes instead of three-fourths of a minute as noted above.

For ventilating the turrets one fan, delivering 2,500 cubic feet of air per minute, has been provided in each turret under the upper handling room taking its supply from the upper handling room and from the space under the upper handling room and delivering into the turret pan and trainers' station. Exhaust has been provided in the rear of the turret pan by louvers in the mantlet plate and holes in the shelf plate. This fan places the turret pan under a low air pressure and is an auxiliary to the gas ejecting system.

McCreery and Magazine terminals, with dampers, have been fitted for all supply terminals, these terminals have been made as light as possible and are nickel plated in quarters and galvanized elsewhere. The exhaust systems, stationary terminals have been used. Openings of McCreery elbows are fitted with portable wire-mesh guards, 1½-inch mesh. Other terminals

have No. 15 B. W. G. National Fabric expanded metal, 1½-inch mesh, portable guards.

All ducts, used for the ventilation of the coal bunkers, are galvanized-steel tubing about ⅛-inch thick, and are fitted with airtight dampers. All openings into bunkers are covered with wire mesh to keep coal out of ducts.

Especial attention has been paid to the ventilation arrangement to avoid the transmission of heat from the engine, dynamo and boiler rooms to other parts of the vessel. In wake of the boiler rooms the air casing under protective deck, and on sides of the uptake enclosures, have been connected to the ship's ventilation for supply and to the uptake enclosures for exhaust. The under side of protective deck within the engine room and the under side of the upper platform within the dynamo room have been fitted with sheathing with an air space. These air spaces are connected to the ship's ventilation for supply and suitable exhaust provided.

All fans are the latest design of electric driven, and are all steel plate with the exception of two 600-cubic-feet-per-minute exhausts, which are cast steel.

DRAINAGE SYSTEM.

The following is a general description of the drainage system, the features covered being as follows:

1. 15½-inch main drain.
2. 5½-inch secondary drain.
3. 4⅝-inch double-bottom drain.
4. 4⅝-inch forward bilge drain.
5. 4⅝-inch aft bilge drain.
6. 5-inch independent drain (Bu. of S. E.).
7. 5-inch independent drain (Bu. of S. E.).

Main Drain.—It is 15½ inches diameter throughout its entire length. It is located on the starboard side close to the coal-bunker bulkhead and extends from the after end of forward fireroom to forward end of engine room, where it branches and runs athwartship, each branch connecting to the main circulating pump.

A 15½-inch stop-check valve is located in each fire and engine room, being in and forming part of main system.

All these 15½-inch stop-check valves are operated at valves and on berth deck in deck plates.

In each engine room, at frame 71, there is a 5-inch connection between the main drain and C. and R. manifold No. 7 and No. 8, located at frame 79-80. This manifold is connected to the fire and bilge pumps in the fire and engine rooms.

Secondary Drain.—It is 5½ inches diameter throughout its entire length. It has connections to all fire and bilge pumps through the C. and R. and S. E. manifolds; also to the handy-billy pump manifold located on upper platform—forward, frames Nos. 42, 43; after, frames, 80-81. The forward and after connections are made directly to the secondary drain. The forward end connects to C. and R. manifold No. 1, located in the forward fireroom at frame 44, and the after end to C. and R. manifold No. 8 in port engine room, frames 79-80.

The forward bilge drain, and chain locker drain are taken by secondary drain through manifold No. 1, located in forward fireroom, frame 44.

The after bilge drain is also taken by secondary drain through manifold No. 7, located in starboard engine room, frames 79-80.

There is a 5½-inch connection from bilge well in each fireroom, and from forward and after end of each engine room.

Double-Bottom Drain.—The double-bottom drain is divided into three sections, each being 4⅝ inches diameter.

The forward section runs between 43 and 61 draining double-bottom spaces under firerooms forward of frame 56. It has a connection to C. and R. manifold No. 3, located in the middle fireroom at frame 58, also to C. and R. manifold No. 4, located in after fireroom at frame 67.

The central section runs athwartship, frames 66-67 connecting to C. and R. manifold No. 5, located in after fireroom, starboard side, frame 67-68, and C. and R. manifold No. 6 in after fireroom, port side, frame 67-68. It drains the double-bottom compartments, outboard of the reserve-feed water

tanks. This also has a connection to the forward section at frame 66-67.

The after section runs between frames 74 and 81 through the starboard engine room and drains the double-bottom compartments between frames 70 and 81. This has a connection to C. and R. manifold No. 7, located in starboard engine room, frame 79-80, which has connection to the fire and bilge pumps.

The double-bottom compartments are flooded through the S. E. manifolds connected to C. and R. manifolds by operating the stop-check lift valves in their respective manifolds.

Forward Bilge Drain.—It is 4⅝ inches diameter and drains all the double-bottom ends between frames 11 and 38 (double-bottom ends at frame 11), and the hold compartments between frames 5 and 11, also forward trimming tanks forward of No. 5 bulkhead. It connects to C. and R. manifold No. 1, located in forward fireroom, frame 44, and is drained from there through secondary drain.

After Bilge Drain.—It is 4⅝ inches diameter and drains all the double-bottom compartments between frames 81 and 98 (double-bottom ends at 98), and the hold compartments between frames 98-100. Also the after trimming tanks aft of bulkhead 100. It connects to C. and R. manifold No. 7, located in starboard engine room, frames 79-80, and is drained from there through the secondary drain.

Independent Drains.—These drains come under the cognizance of Bureau of Steam Engineering. In firerooms they are 5 inches in diameter and run from the bilge wells to the fire and bilge pumps. These drains are fitted in each fireroom.

The independent drains in engine rooms are 5 inches in diameter, and come under the cognizance of the Bureau of Steam Engineering. They are fitted in each engine room, and drain the bilge wells in shaft alley and engine rooms.

The drains in the shaft alley connect to C. and R. manifold No. 7 starboard, No. 8 port, and also direct to Bureau of Steam Engineering manifold, which are connected to fire and bilge pumps in engine rooms.

C. AND R. MANIFOLDS, DRAINAGE SYSTEM.

No.	Frame	Location. Port or Stbd.	
1	44-45	P.	In forward fireroom at centerline.
2	49	P.	In forward fireroom at centerline.
3	58	P.	In middle fireroom at centerline.
4	67	...	In after fireroom at centerline.
5	67-68	S.	In after fireroom, starboard coal-bunker bulkhead.
6	67-68	P.	In after fireroom, port coal-bunker bulkhead.
7	79-80	S.	In starboard engine room at centerline.
8	79-80	P.	In port engine room at centerline.
9	42-43	S.	In passage, upper platform.
10	80-81	S.	In passage, upper platform.

TRIMMING TANKS—PUMPING AND DRAINAGE.

There are four trimming tanks, two forward and two aft. Those forward are flooded by a 5-inch sea connection, frame 5-6, starboard side.

A 3-inch pipe is led to each trimming tank, which is controlled by a 3-inch globe valve, operated at valve and on berth deck in deck plates, frame 5-6.

Those aft are flooded by a 5-inch sea connection, frame 100-101, starboard side. A 3-inch pipe is led to each trimming tank, which is controlled by a 3-inch valve, operated at valve and on berth deck in deck plates.

Draining.—The forward tanks are drained through the forward bilge line to manifold No. 1, frame 44, and the after tanks by the after bilge to manifold No. 7, frame 78-79, starboard engine room.

The extreme forward and after tanks are sluiced into adjacent compartments.

From these manifolds Nos. 1 and 7 water is handled by the secondary drain.

DESCRIPTION OF FIRE MAIN.

The fire main is composed of two systems, 6 inches diameter, port and starboard, located near center line of ship, between frames 43-81, at the forward and aft end, between frames 43-44 and 80-81, the main is run athwartship, thus

forming a complete circuit between frames 43 and 81, extensions from the circuit are made forward and aft.

At frames 43-44, valves Nos. 104 and 105 cut out port and starboard systems. Valve No. 106 cuts out forward sprinkling system; valve No. 103, cuts out forward fire system.

At frames 80-81, valves Nos. 121 and 122 cut out starboard and port systems. Valve No. 123 cuts out aft sprinkling system; valve No. 124 cuts out aft fire system.

Valves Nos. 101 and 102 cut out 3½-inch risers from forward system.

Valves Nos. 109, 110, 113, 114, 117, 118, 119 and 120, cut out 4-inch risers from amidship system.

To play from Plug No.	Open valves Nos. Thus connecting to fire main.	To play from Plug No.	Open valves Nos. Thus connecting to fire main.
1	106	23	109
2	123	24	114
3	103	25	113
4	106	26	120
5	103	27	119
6	103	28	124
7	121	29	131–101–103
8	124	30	101–103
9	123	31	102–103
10	124	32	132–110
11	102–103	33	133–109
12	101–103	34	134–114
13	109	35	135–113
14	110	36	136–120
15	113	37	137–119
16	114	38	132–110
17	119	39	133–109
18	120	40	134–114
19	124	41	135–113
20	101–103	42	118
21	102–103	43	117
22	110	44	144–132–110

To play from Plug No.	Open valves Nos. Thus connecting to fire main.	To play from Plug No.	Open valves Nos. Thus connecting to fire main.
45	145–133–109	49	117
46	134–114	50	144–132–110
47	135–113	51	145–133–109
48	118		

To connect fire main with fire and bilge pumps:

	Port System.	Stbd. System.
Compartment B–1, open valve No.	108	107
B–2, open valve No.	112	111
B–3, open valve No.	116	115
C–1, open valve No.	...	125
C–2, open valve No.	126	...

FRESH-WATER SYSTEM.

From the distiller pump the distilled water is discharged to the fresh-water tanks on the upper platform forward. From these tanks the water is pumped through the distributing main into the reservoir tanks on the boat deck by use of the electric pumps.

All spaces are supplied with fresh water from the reservoir tanks by gravity, and, in order that all spaces may be supplied in case the gravity tanks are out of commission, the electric pumps are so arranged that they can be run continuously, the surplus water being returned to the suction through relief valves fitted in the discharge pipes.

The washrooms for chief petty officers, firemen, servants, and the laundry are fitted with storage tanks from which the fixtures are supplied, while all other spaces are supplied directly from the distributing main or its branches.

For filling the ship's tanks from the deck or water boat, connections are provided near frame No. 30 with a by-pass to the fresh-water main. The filling pipes for the reserve-feed water tanks near frame No. 71 is also by-passed to the fresh-water main.

On the upper deck, between frames No. 43 and No. 44, port side, a 1½-inch hose connection is fitted for supplying fresh water to the steam cutters.

SALT-WATER SYSTEM.

The sanitary or flushing system is supplied by a direct connection from the distiller circulating pump and a by-pass from the fire main.

All the plumbing spaces except the crew's washroom and the crew's head are supplied by this main, and a branch near frame No. 39, berth deck, is run to the circulating pump in the ice-machine room.

The crew's washroom and the crew's head are supplied by an independent system, through two electrically-driven centrifugal pumps, drawing from an independent sea valve. This system, for crew's spaces, is also fitted with a by-pass from the fire main.

HEATING SYSTEM.

All pipes for the heating system consist of seamless-drawn brass pipe, iron-pipe size; fittings, flanges and valves of composition.

Radiators, consisting of pipes led along deck, are made up of 2-inch pipe; those installed on bulkheads consist of coils, made up of 1-inch pipe. Radiators in crew's spaces are fitted with key valves, those in officers' quarters with valves having fixed handwheels; valves being provided with union on outlet end so that radiator can be taken down without disturbing the lines. Radiators are divided into two or more sections where the area exceeds eleven or more square feet, each section being provided with independent steam, drain and air valves to avoid the necessity of having steam on the entire heating surface during mild weather.

All radiator pipes, fittings and valves are of polished brass; where the size does not exceed 1½ inches the connections for circuit steam and drain pipes are made with screwed fittings, but above that size flanges are used.

Watertight connections at decks and bulkheads are made with composition stuffing boxes and copper U-bends installed throughout the lines to provide for expansion.

The steam supply to radiators is divided into two systems, one forward and one aft, and is taken from the auxiliary steam lines in the fire and engine rooms respectively, the connections at the auxiliary lines being fitted with pressure gauges, stop, relief and reducing valves. The steam is then carried to distributing manifolds on the berth deck and divided into circuits—the forward system into five circuits and the after system into seven circuits—each circuit being fitted with a stop valve so that it can be operated independently.

The steam supply to galleys, pantries, bakery and plumbing heaters is likewise taken from the auxiliary lines, fitted with gauges and valves and divided into two systems, one forward and one aft. The steam to forward system is carried to a distributing manifold on berth deck and divided into three circuits, one of which is by-passed to a circuit from the radiator steam manifold. This circuit supplies all radiators and plumbing heaters on the main deck forward and can receive steam from either manifold, stop valves being provided in all branches to radiators in order to operate steam to heaters independently. The remaining two circuits are entirely independent and have no connection whatever with the radiator circuits. The after system consists of one circuit and has no distributing manifold, but wherever a branch occurs a stop valve is fitted in same close to main. The exhaust from radiators is also divided into circuits and led to receiving manifolds, each circuit having a stop and check valve to prevent water from one circuit backing up into another. The discharges from manifolds are led to traps in engine rooms, and the drains from these traps are connected together and lead to drain manifolds. These manifolds, of which there is one in each engine room, are by-passed and discharge directly to port or starboard filter tank or to another manifold which is arranged to discharge to main or auxiliary condensers or filter tank. The drains from the plumbing heaters have no

connection whatever with other drains, and are carried directly to the auxiliary exhaust lines.

Particular care has been taken to prevent water hammer, and as all drains lead downwards no pockets have been formed.

The steam to radiators has been arranged to work at 50 pounds, and the steam to galleys, pantries and water heaters at 30 pounds per square inch.

All systems are tested at 150 pounds per square inch.

ASH HOISTS.

The ash-hoist engines were designed and built by the Hyde Windlass Company, Bath, Maine. They are located in the upper hatches, the ventilator trunks containing the bucket guides, ropes and sheaves, etc. The hoist is operated from and hoists to the upper deck, the bucket-guide rails extending from the bottom of the ventilator trunk to a point well above the upper deck, with trolleys at this deck for delivering ashes to the chutes at the ship's side. On the test 300 pounds were hoisted from the fireroom floor to the upper deck in five seconds, including starting and stopping, with 100 pounds steam pressure.

The hoisting engines are of the reciprocating type, with a rope drum, fitted with a follow-up and reversing gear, and an adjustable safety gear to prevent overwinding and stop the engine when the ash bucket reaches the fireroom floor.

DATA FOR ONE ENGINE.

Number of cylinders	2
Diameter of cylinders, inches	4½
Stroke, inches	4½
Diameter of drum, inches	10
Number of ash-hoist engines in ship	6

FORCED-DRAFT BLOWER.

The forced-draft blowers are located over the firerooms, outside the hatch enclosure. The motors were designed and built by the General Electric Company; fans supplied by Sirocco Blower Company.

The arrangement is the same for all of the firerooms, there being four motors, each driving one fan, located outboard, and so that the air is discharged directly to the fireroom about over each boiler. The supply is taken from the fireroom-ventilator ducts, which are closed at the bottom when under forced draft.

The motors are designed for speeds varying from 650 to 1,050 r.p.m. developing from 6 to 22 H.P., and are wound for 125 volts.

The fans are of the Sirocco type, 31-inch diameter, with a capacity of 17,500 cubic feet of air per minute at 2½-inch air pressure. Area of induction nozzles for one fan = 5.9 square feet; reduction nozzle, 6.525 square feet.

MACHINE SHOP.

The machine shop is located amidships on the berth deck forward of the after 12-inch barbette and between the machinery hatches, access to it being from the athwartship passage and from the engine rooms through their respective entrance hatches. The machines are arranged with independent enclosed motor drives of General Electric Company's make.

The following machines are installed:

1 28-inch extension gap lathe;
1 12-inch tool-room lathe on bed of gap lathe;
1 14-inch engine lathe;
1 16-inch crank shaper;
1 31-inch radial-drill press;
1 16-inch sensitive-drill press;
1 30-inch grindstone;
1 Universal milling machine;
1 12-inch emery grinder;
1 Combined hand punch and shears;
6 Bench vises.

The tools are provided with the most modern attachments, including scroll and drill chucks, index head, automatic cross feed, swivel table, pipe vises, etc., and all necessary tools, drills and cutters.

NOTES.

THE MODERN NAVY—AN ENGINEERING AFFAIR.

Address by Rear Admiral George W. Melville, and Presentation of Portrait.

On the occasion of the recent Convention of the American Society of Mechanical Engineers at Washington Rear Admiral George W. Melville delivered a brief address on the position of the engineer in the United States Navy. At the close of the address a portrait of Admiral Melville, painted by Sigismond de Ivanowski, was presented by friends of the Admiral to the National Gallery at Washington.

In the course of his address Admiral Melville said that ten years ago his presidential address before the Society had dealt with almost the same theme. At that time the Personnel Law was passed, which amalgamated the engineer corps with the line or executive officers of the Navy, with the understanding that henceforth engineering was to be the function of these line officers. In his report as Chairman of the Personnel Board, ex-President Roosevelt, then Assistant Secretary of the Navy, said: "On the modern war vessel every officer has to be an engineer whether he wants to or not." It is well that these lines should be constantly in mind, for they set forth the only justification for the Personnel Law.

Discussing the effect of the amalgamation in practice, Admiral Melville said that the commanding officer was now the master of the entire ship. In his early days few commanding officers felt any interest in the machinery beyond their demand that it should always be ready for service. If anything went wrong they washed their hands of the responsibility, which was naturally upon the special body of engineers. They now felt the same keen interest in the machinery that they did in

the guns or any other part of the ship, and the chief engineer of the ship (still so-called) was generally looked upon as the officer next in importance after the captain.

The part of the new régime about which he had felt misgivings was that thus far there had been no systematic effort to assure training and experience for every line officer in connection with the motive power. Every young officer should be required to serve an apprenticeship in the engine and fire-rooms, just as he did on deck, but so far as he had been able to learn there had never been careful attention given to this point.

Present and Future Design.—Having touched upon the general conditions of the executive side of engineering as affecting the operation and integrity of the machinery at sea, the Admiral proceeded to make a few remarks on the prospects with regard to present and future designs. Thus far, he said, this work had remained in the hands of officers specially trained. Unfortunately, the same condition was to be found here as that mentioned in the previous division of the subject. An effort had been made to arouse the interest of some of the younger line officers by a course of special training for this most important work after the present highly competent and experienced men had retired. There had, however, been no settled policy for this, and the attempt that was started was interrupted by the cruise of the Atlantic Fleet. "I am very glad indeed," continued Admiral Melville, "to bear testimony to the fact that the recent designs of the Bureau of Steam Engineering have been highly creditable in every way. In saying this, I feel a touch of personal pride, for the reason that the men who have been doing this work were formerly my assistants and received most of their experience during my term of office. I am naturally pleased that the record which was made during my own term is being maintained.

"When such praise as this can be given in simple truth, what can be thought of the official who plans to discredit the men who have made such a record, and destroy the autonomy of

the Bureau by subordinating it to the Bureau charged with the design of hulls? I think it will be agreed that my service of a lifetime in the Navy and my record as the head of a great Bureau in the Department, the longest since the Civil War, entitles my opinion to some weight, and I want to register my earnest conviction that any such scheme of consolidation can only bring inefficiency, retrogression and waste.

The Work of the Navy Yards.—"There is still another side to engineering in the Navy, namely, the work of the Navy yards, which has been prominently before the public during the régime of the last Secretary of the Navy. Changes have been made abolishing the separate departments in the Navy yards, and consolidating their administration under one officer, whose work, while a vital element in the building of a ship, was certainly not the only important part and, moreover was so different in its nature from the other departments which were absorbed, that it is obvious he could not be an expert on these other lines. To me it was so marvellous as to be almost beyond belief that in this age of specialization a movement so absolutely counter to the spirit of the age should take place in the name of economy and reform. If the great shipyards in civil life, or the great manufacturing establishments, or the dockyard administration of other countries, had been different from the methods employed in our Navy yards, a change would at least have been indicated; if, in the other places to which I have referred a system somewhat like the one which it has been attempted to introduce in our Navy yards was in vogue, there could be some understanding of the change. The facts are, however, that in its essential features our Navy-yard administration was along the very lines which obtain in foreign dockyards, in the great shipyards at home and abroad, and in our great manufacturing establishments.

"I am led to believe that the present Secretary is giving the matter very careful consideration with a view to undoing the tremendous harm brought about by his predecessor, and I trust he will be well advised and will restore the yards to their former efficiency. It ought to be said, however, as a matter

of record, that these changes were made without any consultation between the late Secretary and the officers most competent from long experience to know what was best. Indeed, by his own statement, the scheme was evolved from his own inner consciousness.

"Our modern Navy is essentially an engineering affair. The vessels themselves are the product of the engineer's brain, and their successful maintenance and utilization depend entirely on engineering skill. Ten years ago I said that the change which had been made, absorbing the engineer corps into the line of the Navy and making every officer an engineer, was a tremendous step forward, provided a sincere and earnest effort was made to carry out the scheme which was thus outlined.

"From what I have said, it will be clear that I am not as yet satisfied that this has been brought about. Undoubtedly the responsibility for the machinery of our vessels, guns, motive machinery, electrical machinery, torpedoes, etc., is upon the line officer of the Navy. He is charged with this duty by law. If the older officers of the Navy had taken hold of this matter with enthusiasm I believe that it would now have been settled, and there would be no question as to the great success of the new officer, the line officer of the twentieth century. I am not willing to believe (and, indeed, hardly willing to consider) the possibility that naval officers will neglect any duty with which they are charged, and I still hope that the scheme will be worked out to a great success.

"Not much is ordinarily said about the machinists who are doing good work on board our vessels. They look after the routine work of repair and adjustment on board ship, but they are without the scientific training which is required for engineers who are really qualified for the duties comprehended by that title. If the line officers of the Navy do not maintain engineering efficiency it will then, as the organization now stands, fall upon these machinists to perform the work of the engineers. In other words, in an organization whose efficiency is absolutely dependent upon the skill of engineers the men

relied upon for such work would be relegated to a position of inferiority, so low that they are hardly counted. This is utterly un-American, and can only be matched by absolute monarchies or countries as unprogressive in the mechanic arts as Spain. The speedy destruction of her Navy in the war of 1898 was due even more to her utter incompetence in engineering than in gunnery. It is inconceivable that self-respecting men in a free country like ours will attempt to perform work of such vital importance without adequate recognition in the way of rank and position.

"I will not permit myself to believe that we shall have to consider this as a practical question, because I cannot conceive that naval officers would fail in duty, but I have felt that both sides of the question, so vital to our naval efficiency, should be presented.

"During my entire career in the Navy, it was my constant endeavor to show by my work the importance of the engineer and to encourage that spirit in my subordinates. I trust I shall not be accused of vanity if I say that I believe my record as engineer-in-chief added a little to the reputation of engineering. My active work in the Navy is done, but so long as I live my interest will never slacken and my voice will always be raised to encourage efficiency in every branch of the service."

Presentation.—Mr. Walter M. McFarland, in presenting a portrait of Rear Admiral Melville to the National Gallery, remarked that, in his judgment, the Admiral's chief characteristics were indomitable courage and unbending honesty. It was possible for a man to have great mental ability and yet fail of true greatness if he lacked these essentials.

They all knew Melville's Arctic record, which first brought him an international reputation; there he displayed a heroic courage which has never been surpassed, and for which Congress advanced him a grade in the Navy. This, however, was only a repetition of other instances of absolute fearlessness, beginning with his earliest days in the service. His professional courage was also remarkable, and along with this was a faculty, which was characteristic of all great men—that

having made his decision he did not worry about the result. A notable instance of this kind in Melville's career was his use of triple screws for the *Columbia* and *Minneapolis*. His ability as an executive was of a very high order. He had a rare talent for choosing able assistants, and, having proved them he left in their hands all the detail work, thereby giving himself time for careful study of the larger problems. The effect of this was very marked in stimulating the entire staff to the highest efficiency and zeal.

With respect to his professional work, it was notable that his career as Engineer-in-Chief of the Navy, from 1887 to 1903, was the longest on record. It covered the building of the "new Navy" and the Spanish war. During this time he was responsible for new designs of machinery for about 120 vessels, among which were 24 battleships and 41 armored vessels. Best of all, there were no "lame ducks" and no failures.

He was the first to use water-tube boilers in large war vessels, and to determine the actual coal consumption by trials. He was also the first to use the method of determining trial speeds, known as the "standardized screw," which is the simplest, most accurate and inexpensive, and fairest to the contractor as well as to the Government.

It was to him also that they owed their first high-speed battleship. When in 1898 the proposals for the *Maine, Missouri* and *Ohio* were being prepared, he stood alone in his demand for eighteen-knot ships. If he had not persisted they would have been three years longer behind the other Navies of the world in battleship speed.

It was very interesting to note also that only a little after this he proposed an "all-gun one-caliber ship"; in other words, what is now called the *Dreadnought* type. Possibly the same influence which almost prevented the eighteen-knot battleships prevented consideration of this more advanced type. At all events, Melville was in advance of the general naval mind, and the United States lost the credit for the introduction of this revolutionary improvement which it might have had several years before the *Dreadnought* was disclosed.

During the war with Spain he brought out the repair ship and the distilling ship. The idea of the former was not new, but the *Vulcan* was by far the most complete vessel of the kind equipped up to that time. The latter furnished fresh feed water to the boilers and enabled a vessel with a storage bunker capacity of 3,000 tons to supply 60,000 tons of water.

A clever piece of work at this time was the fitting of new boilers to some of the old Civil War monitors to enable them to be used for harbor defence. For years Melville had advised the Navy Department that new boilers must be supplied before these vesels could be used. When the destruction of the *Maine* made the outbreak of hostilities seem probable, the makers of water-tube boilers submitted estimates of time and cost for the work. Boilers were promised in thirty days, but it was necessary to use the standard land type. As these vessels were not to go to sea, however, this was satisfactory. The worn-out boilers were cut up and passed out through the smoke pipe (because the armored deck could not be taken up), the new boilers were passed down the smoke pipe in sections and erected on board; finally each of the boats was given a steam trial, which was entirely successful.

A great deal of experimental work was done under his direction, all of which is published in his annual reports. The last of such experiments was a series of tests of oil fuel, probably the most comprehensive ever made.

A tribute to the Admiral's striking personality follows.—"Pages Weekly."

THE FUTURE OF NAVAL ENGINEERING.

In discussing the above question "London Engineering" says —

We should have preferred precedence to be given to some of the questions vitally affecting the efficiency of the Fleet, and, by preference, the subject of the position of engineers in the Navy. This touches the fighting power of the Navy at all points, as the present position is anomalous, and a source of

possible weakness. History has many examples of failure in war owing to the absence of an absolutely perfect understanding between all the officers responsible for action. We do not for a moment think that the engineer officer or the military officer would willingly do anything to jeopardize the issue of an engagement. But when there exist conditions which are conducive to possible misunderstanding, or which may create grave doubt as to the respective duties and responsibilities of the officers in each department it cannot be said that the officers in the Fleet are satisfactorily circumstanced for the display of that initiatory courage which is so valuable a factor at the crucial moment in an action. The situation has been intensified by the entry of the new engineer officer, who will have status and disciplinary powers over the engine-room personnel superior to those possessed by the head of the department in which he is serving. A statement of the case, clear in exposition and temperate in tone, has been prepared for circulation to Members of Parliament in view of the forthcoming debates. The facts stated carry their significance, and establish a case for a comprehensive change in the position of the present engineering officers in the Navy. There is, therefore, no need to dwell upon this phase of the question here.

The situation in respect of the officers of the future is no less serious. As has been clearly explained in previous articles, the scheme of 1902, with the additions and amplifications of 1905, discontinued the entry of naval engineer officers as a distinct class, and ordained that, on the disappearance in course of time of the present officers, engineering duties would be carried out by specialized naval lieutenants (E.), and that the latter, on promotion to commander, might resume deck and fighting duties, and eventually be able to rise to the ranks of captain and admiral. Although experience of the training of the embryo officers of the future is reassuring so far as the general result is concerned, the opinion is developing strongly that naval engineering as a profession, as distinct from a trade, will become extinct. In the course of a few years it will no longer be a branch of the service, but only one of the many

duties undertaken by the general body of executive naval officers, the necessary personnel being found from among them by the same methods which provided those who for years have carried out special gunnery, torpedo and navigational duties. It is the opinion of many, who founded their belief on the fact that as the lieutenant (E.) will be a naval officer, engaged only for a time on engineering duties, (1) the real working of the machinery department will become absorbed by the artificers and mechanicians, who in time will agitate for improved status, &c., thus opening up the question again; and (2) the naval spirit of the lieutenant (E.) will clash with the civil spirit of the men under him.

To fully understand the contention of the first statement it is necessary to trace once again the career of the lieutenant (E.). In common with all officers, he enters Osborne College, and after two years there is transferred to a similar institution at Dartmouth. The instruction received at both these establishments is of a general nature, embracing seamanship, engineering, navigation, gunnery, &c., and is not planned with a view to his eventually serving in one particular specialized branch. As midshipman and sub-lieutenant his instruction and duties follow on the same diverse lines, his work afloat, now being entered upon by the first of the youths being trained under the new system, will partake of that of the sailor, engineer and artillerist. After about 5½ years' sea service, he will be ordered to prepare himself as a specialist, in this case as a lieutenant (E.), either in accordance with his own wishes or as selected for him by the Admiralty. He will then proceed ashore to undergo a further course of about twelve months at one of the dockyards, his studies being limited to engineering. On the conclusion of this he will join a commissioned warship as lieutenant (E.). Having a rank and status and disciplinary powers far exceeding those of existing engineering officers, entered under the old system and in positions of greater responsibility, there is grave danger to efficient administration.

He will be brought into contact with the higher ratings of the mechanician, artificer and stoker branches, chiefly petty

and warrant officers, all elderly men, who have passed the whole of their service career in the engineering department, and who are the most expert and highly-paid men in the ship. Under the system of distinct naval engineer officers the position of these ratings was one of importance and responsibility, especially in small ships; but how much greater in those respects will it become when ultimately they have only the "sea officer with a mechanical training" in command over them? However keen the lieutenant (E.) may be, and though he may be actually capable of exercising the necessary supervision, it is only natural that he will be regarded by these men as but an amateur in engineering, whose instruction in that subject has been superficial, and whose capabilities must not be placed under too great a strain. No doubt a number of lieutenants (E.)—especially those who intend to remain as permanent specialists—will, from sheer ability and strength of character, force those under them to recognize their work and technical knowledge. But it is to be feared that many will not be able to turn their intermittent engineering training to such good account; and while recognizing the long experience, great knowledge and splendid character of the engineering petty and warrant officers, they will gradually allow the grip of things to pass out of their hands into those of the latter. Further, the Admiralty seem to have purposely given color to this view, as in one of their publications they expressly state that the work of the lieutenant (E.) is to be chiefly "observational." There are many who remark, "Precisely so—and nothing else." Since machinery is becoming more and more complicated, requiring more and more scientific knowledge and practical experience in its efficient maintenance and satisfactory running, any change tending to deterioration in the skill and resource of those responsible must be condemned.

As a counter argument against this line of reasoning it may be urged that no such trouble has been experienced in regard to the lieutenants (G.) and (T.). They are the gunnery and torpedo experts of the ship, and do not delegate a particle of their position to the gunner, seaman-gunners, &c., under them;

therefore why should the lieutenant (E.)? But the conditions are not similar. The gunnery and torpedo ratings are specialized seamen in the same manner as the lieutenants (G.) and (T.) are specialized sea officers. But the leading men in the engine room are not specialists in the same sense; their training and experience have not been grafted onto other subjects, but have been connected with and centered in engineering, and that alone. If a new branch of "gunners" was established, consisting either of men solely trained as such, or who had entered the service from private firms as finished craftsmen, then the conditions would be alike, and it is possible that such men would be more fitted to instruct the lieutenant (G.) than to follow his guidance.

Should such a state of affairs as we have foreshadowed eventually come to pass it would closely resemble the conditions which existed for some years subsequent to the introduction of steam propulsion in the Navy, when the responsible engineers were fitters and mechanics, mostly recruited from the workshops in which the engines had been constructed; men often with but little education, and who could only rise to the rank of warrant officer. But as steam navigation increased, both in the number of steam warships and their horsepower, these men appreciated their position, and agitated for improved status and higher pay. Although such recognition was for a time strongly opposed by the "sailing" officers of those days, the upward progress of the men who controlled the machinery could no more be held back than the advance of mechanical science itself. The result was the institution of the commissioned rank of naval engineer, with suitable emoluments and position in the service. But now, after an existence of many years, the disappearance of this class has lately been decided upon; their work to be carried on by the executive line of naval officers in the person of the lieutenant (E.). But it is only a logical conclusion to assert that if these new specialists are not as well fitted and trained for their special duties as were the officers whom they displace, the real control of the machinery will again revert to the skilled mechanics and fitters, who,

without doubt, will be prompted by the same motives, and act in a similar manner, as their predecessors.

As regards the second statement—viz: that the naval spirit of the lieutenant (E.) will clash with the civil spirit of the men under him—a little consideration should be given to the disciplinary conditions which have to be conformed to by the seamen and by those in the engine-room branches. On deck smartness, discipline and drill are undoubtedly necessary, and by many are considered as the very breath of naval life; and very properly so, as the greater portion of the work of the naval fighting man is of an artificial nature, and needs a stimulus, for, with the exception of those whose duties are actually necessary for the navigation and routine of the ship, which employ but few, his time is taken up in preparing himself for the day of battle. It is the same with the fighting branch of the Army, all drills, maneuvers, &c., are purely preparatory, and the duties of neither the soldier nor the sailor are the same as those of men whose daily task consists of work which it is essential for them to complete. In other words, they are students; and as it is very advisable, though not actually imperative, for them to study, self-restraint or discipline has to be brought to bear. Experience proves that when the period of preparation gives way to one of stern reality, drill, discipline, &c., have a tendency to disappear, as in war a fleet or army, though infinitely better fighters, are never quite so "smart" as in time of peace.

But as regards those employed in the engine-room and stokehold, they have not entered the service to prepare themselves for anything; they are there to carry out certain duties for the propulsion, ventilating, lighting, &c., of the ship. Their test of ability is not only on the day of battle, it is occurring every hour in one shape or another. For them no artificial stimulus need be provided; they have sufficient in the fact that certain essential work has to be undertaken and carried through to enable the fighting man to become efficient. To further facilitate the process of tuition or preparation of the latter, instruction is given to him by means of verbal orders or drill,

but there is no more need for a stoker or artificer to work by "words of command" than there is for the cook or sick-bay attendant to do so. These conditions have always been recognized, the men in the engine room have never been trained to exhibit, nor has their work ever demanded, that military discipline and smartness which is so conspicuous a feature of the seaman branch. But the lieutenant (E.) will differ from the naval engineer officer of old in being firstly a naval officer, and secondly an engineer; whereas the other was a thorough marine engineer who happened to be serving in the Navy. The lieutenant (E.), imbued with the naval spirit, may therefore be inclined to expect from those under him the same discipline, &c., that he has always experienced in the executive branches, and those, therefore, who maintain that the smooth working conditions which have always existed between the officers and men in the engine room will disappear on his advent have undoubtedly a certain foundation for their argument.

THE NEW MIDSHIPMAN.

The question of the education and training of the future engineer officer of the Navy is a matter of much comment abroad, and the following editorial from "Engineering" will tend to reflect an engineering opinion on the subject of the present system of training engineer officers for the British Navy:

In his statement explanatory of the Navy program, the First Lord of the Admiralty intimated that a circular-letter had been issued to the Fleet defining clearly the principles governing the training and instruction of the "new scheme" midshipman, and laying down detail instructions for carrying out that training during the three years the midshipman will serve afloat. A study of this circular-letter does not dispel the doubts which engineers have entertained regarding the efficiency of the new system of training, so far as it affects the

future management of machinery on board ship. The scheme is sound so far as it is concerned with the general training of officers without distinction; the curricula and subjects of examination have been prepared with great care. But no one can study the details without realizing that what is lacking is provision for that practical experience which can only come with direct contact with problems and matériel.

The Osborne course need not be dealt with here. It follows generally the lines of the leading educational institutions which aim at affording a liberal education to the earnest and studious youth, and the authorities have very properly determined that during this course at Osborne, as well as that at Dartmouth, there shall be no specialization. The scheme, the First Lord points out, is being carried out satisfactorily, the only slight modification made being that a greater number of cadets are required to take up the study of German as well as French, so that a larger number of officers will be grounded in the former tongue, in order that the supply of interpreters in German shall be increased. As is known, the cadet spends four years and eight months in the colleges and on board the training cruisers, and at the end of this period the cadet becomes a midshipman, and will undergo a three years' training afloat, in order to provide "sufficiently for his thorough knowledge of the practical work of his profession." He thus avoids the necessity for the present courses in gunnery, torpedo and pilotage prior to the examination in these subjects for the rank of lieutenant. The duties of the new naval instructors appointed to ships carrying the "new scheme" midshipmen will be generally as follows: To superintend the observations and the working out of the ship's position every day at sea by those midshipmen who are not attached to the navigating officer; to assist the specialist officers with the theoretical instruction of the midshipmen in the various professional subjects; to encourage voluntary study, and to help the midshipmen who wish to keep up and improve their educational acquirements; to assist any commissioned officers who desire to work up for specialization. During the three years' course annual exami-

nations will be held, the papers being sent down from the Admiralty relating to all the subjects of the compulsory parts of the examination for lieutenant. The examinations will be framed to test the experience gained in the practical side of professional work; but special advantages will be offered to those who also take up the theoretical side.

It is with the provision for acquiring practical experience that we see possibilities of failure. During the three years' service at sea the midshipman will work with the executive officer for training in officer's duty and seamanship, and with the specialized officers for training and instruction in gunnery, torpedo, navigation and pilotage, and in engineering. The apportionment of the time to be allotted to each subject is to be left for the present with the commanding officer, but "about one-third of the whole time is to be spent with the engineer officer." Again, the periods of instruction in each subject "are to be arranged so that the time devoted to any particular branch shall not be so long as to entail any risk to the midshipman getting out of touch with other branches of their professional work." This last proviso is, in itself, an admission of the weakness of the scheme. It may be taken that the three years' course is analogous to works apprenticeship following upon a liberal education, and it would seem as if the Admiralty, although responsible for the drafting of the system, failed to recognize the extreme danger of the apprentice attempting too much within a limited period. We are prepared to admit that every effort will be made to utilize the time available to the fullest advantage. It is laid down that officers, and not seamen instructors, are to be employed, that the midshipman is not to be asked to do any ship's clerical work, and that every opportunity is to be given for studying the work done under the best guidance. We have no fault to find with the arrangement in so far as it affects the purely military officer—or, indeed, the navigating officer—and it is conceivable that a sufficient knowledge may be gained of gunnery and torpedo work. But there is still room for doubt as respects these two latter, in view especially of the multiplication of mechanical details

of extreme delicacy, and the rapid development in these branches of applied science. As regards engineering, we are satisfied that one year's practical experience is absolutely inadequate, especially as the indications point to the work being largely observational.

The midshipman, for instance, is during this period expected to become closely acquainted with the practical work of the engineering department, "learning the methods and practice adopted in harbor for the care and maintenance of machinery, as required to keep it in good order; and acquiring the knowledge and experience under way which will enable him, by the time he comes up for examination, to take the duty of engineer officer of the watch." He is to "see" such repair work as is going on in any department and take part in the examination of the hull and machinery. He is also to take advantage of such opportunities as present themselves of "seeing" engineering operations in the dockyards. He is to keep a note book with descriptions and detailed sketches of parts of machinery, &c., and with accounts of any repairs he may "witness," and the reasons for the repairs. An examination of this book is to be included in the final test for lieutenancy.

A serious deficiency in the scheme, as enunciated by these extracts from the circular-letter, is the absence of practice. Assuming that a number of the midshipmen will anticipate the ultimate choice of engineering as their specialty in later years, and will early apply themselves with diligence and determination to acquire the fullest knowledge and experience, the period is too short and the method too nebulous. One might as well expect the medical student to become an adept in surgery by a close observance of such masters as Treves or Horsley; it will be universally admitted that a thousand years of such observation would fail to give the student that intimate knowlege, courage and deftness which alone come with practice. Similarly, the embryo physician in attendance at a hospital can never acquire intimate knowledge of the ailments of the human organism without being permitted to diagnose cases even under the eye of his teacher. The mechanism of a ship is recognized

as parallel to the organism of the human body; its intricacies are as great and its possible ailments as numerous, and the engineer has not the same advantage as the doctor of a personal interview with the patient.

The public would look askance at any attempt on the part of shipowners or the Board of Trade to grant a watchkeeping certificate to anyone, however liberal his preliminary education, who had spent only one year watching others driving and repairing the machinery of a merchant ship. The entrusting of the machinery of a vessel, even of the cargo type, to such a one would be courting disaster, and would almost result in a charge of culpable negligence. In the merchant service an apprenticeship to engineering is regarded as an essential preliminary to sea experience, and this latter must be extensive before a certificate is granted, or before responsible owners of a passenger ship would entrust the duties of watchkeeping. In the Navy, on the other hand, the preliminary training, however satisfactory, is not specialized; yet the Admiralty regard it as possible that one year's observational experience suffices to justify them in granting a watchkeeping certificate. In the merchant service life is at stake; in the naval service the national safety may be jeopardized.

In measuring the time necessary to gain experience it must be remembered, too, that in the Navy, to a far greater extent than in the merchant service, the engineer must keep pace with contemporary knowledge; the same, indeed, applies to the gunnery and torpedo student. Consequently, the acquisition of knowledge of what is going on on board ship is not sufficient training. Attention must at the same time be devoted to contemporary developments. No doubt, following upon specialization, the lieutenant would be required to make a study of such developments; but, as shall presently be pointed out, the age at which specialization takes place is somewhat beyond the period of enthusiasm in the acquisition of knowledge, especially if one has been forced into a profession instead of voluntarily choosing it as a consequence of personal predilection.

After the three years' sea training, during which the com-

manding officer, in apportioning the time for training in the various subjects, plays with the midshipman the game of battledore and shuttlecock, the young man is required to sit for final examination to qualify for the rank of lieutenant. This examination will consist of six parts; five—seamanship, navigation and pilotage, engineering, gunnery and torpedo—being compulsory. Two voluntary subjects must be taken, the list including practical mathematics, mechanics and heat, electricity, advanced French or German, another foreign language and naval history. A first-class in any of the six parts, two voluntary subjects being one, will count two marks, and a second-class one mark. Should the midshipman get all twelve marks, he will only require to serve nine months more as a sub-lieutenant before reaching the rank of lieutenant. The period of additional service increases with decreased marks. If five marks are not secured, the officer will be sent to sea, and must present himself on the next occasion for examination in the subject or subjects in which he has failed, losing two months' time in respect of each subject in which he has failed. A second failure will entail the liability of removal from the service. The engineering part of the examination is to be carried out by officers nominated by the Commander-in-Chief at Portsmouth, after communication with the Engineer-in-Chief and the Director of Naval Education. No exception can be taken to the machinery for examination: all depends on the test; and here also it must be admitted that the scope of the curriculum in engineering is comprehensive.

The minimum time of training afloat for the rank of lieutenant is thus three years and nine months, the maximum being about five years. But of the second period of from nine months to two years, one-half must be spent as an officer of the watch on deck. The proportion of time to be spent in the engine room is not stated. After becoming a lieutenant, officers will be selected to specialize in one or other of the various branches of gunnery, torpedo, navigation or engineering, and will attend a course of two terms (approximately six months) at the Royal Naval College, Greenwich. "This course of in-

struction will comprise such studies as will fit the officers to prepare for the practical courses of specialization." There is no indication as to whether the Admiralty will themselves select or give option to the officers to choose which department of the service they will enter.

It is significant that before requiring to specialize the lieutenant has become twenty-one or twenty-two years of age, and up to that point his training has been so varied that it will be difficult for him to cultivate an enthusiasm for any one department. Under the old conditions the engineer student was brought into direct contact with constructional engineering, repairing engineering, and with the management of machinery on board ship from his entry into the service as a lad. He grew with and became almost part of his profession, acquiring much resourcefulness in dealing with every possible contingency on board ship, and developing a courage which is of incalculable benefit to the engineer in dangerous emergencies. "Specialization" is a watchword of progress, and anyone who attempts a general knowledge and practice of everything to the neglect of a full knowledge of something, whether he be scientist, chemist, surgeon or engineer, cannot hope to advance in his profession or to serve his generation, however estimable he may appear as a universal exponent of surface knowledge, or as a provider of articles invented or discovered by others.

It seems absurd to require the young man who intends to become an engineer to waste his time in mastering minute details of rigging, boat landing, navigation, signalling, or, indeed, ancient naval history. These should be more or less voluntary; they may be desirable in the interest of relaxation. But as soon as a liberal education is completed—such an education as is no doubt afforded at Osborne and Dartmouth—the youth ought to be encouraged or required to specialize before he loses the first sharp edge of the desires of ambition. These are but truisms, and when one recalls them it seems the more surprising why the radical changes embodied in the scheme should be brought into a branch of the service which has

always been exemplary in its efficiency. Moreover, the requirements of engineering are becoming more and more exacting. The intricacies are increasing, the extent of special knowledge is being intensified, and, consequently, the preparation for practical work requires longer time, greater enthusiasm and more continuous concentration. Unless modification is made at an early date as the result of experience, there is grave danger that the practical work of engineering on board ship will devolve upon the mechanics and artificers, and recent developments do not justify faith in their possession of such knowledge of thermodynamics or mechanics as is necessary to ensure the efficiency of the propelling machinery on board ship, and this—it is not necessary to enforce—involves the efficiency of the naval defence of the country.—"Engineering."

THE NEW MECHANICIAN.

Another matter over which Engineering opinion in England is very much exercised is the establishment of the new mechanician rating, as the following two extracts from "Engineering" will show:

The new mechanician, like the new midshipman, under the new Admiralty system of training, is now afloat, and the influence of the former on the efficient steaming of warships is as important a subject of inquiry as the probability of the latter becoming a completely satisfactory engineering officer. Some may say that the subject is even more vital when they reflect on the inadequacy of the experience which the new midshipman will derive from his preliminary training afloat, as reviewed in our article last week. For in such a case the engineering officer must depend, more or less, upon the knowledge of machinery and upon the resourcefulness of his subordinates. In small ships, too, the full responsibility of watchkeeping will devolve upon the new mechanicians, as has been the case with the existing artificers. Has the evolution of the

Admiralty scheme as regards engine-room artificers and the new mechanicians, since it was first promulgated, afforded proof that this knowledge and resource will be possessed by those who are to keep watch with the new engineering officers of the Fleet? The doubt entertained by so many engineers of high repute with the Royal and mercantile marine and in the great constructional works is intensified rather than dispelled by the fuller study of the situation now rendered possible by the lapse of time, and by the entry into the service of the new mechanicians.

For a better conception of the situation it is necessary to repeat much that may be known to those who have followed the scheme from its origination. Without that it is not possible to make a definite comparison between the new scheme and the old. The 3,000 engine-room artificers in the Fleet have been recruited from the great engineering factories in the country, where they served a full apprenticeship in some department of mechanics, and have, in many cases, had experience also as sea-going engineers on merchant ships, holding in such cases the Board of Trade certificate. All have applied themselves, too, with commendable diligence and studious application to the acquisition of that special knowledge necessary to watchkeeping and other work in the Navy. Their function has hitherto been to serve under the engineer officers as watchkeepers, and without engineering officers in small craft, as well as to undertake in the factory on board ship such repair work as is possible of execution while the ship is in commission. A plebiscit of the engineering officers in the Navy would, we are certain, establish the view that this work has been admirably executed, and the Lords of the Admiralty themselves have evidence of an even more direct character in the small amount of repair necessary in the case of ships returning from commission. Indeed, in recent times many ships have, on completion of two years' commission, proceeded to sea on a new commission without any machinery repairs being undertaken in the dockyards. Without any reason which can carry conviction to the en-

gineering profession generally the Admiralty, acting upon the report of Admiral Douglas' Departmental Committee, decided to confine the work of the artificers to repairing, and to promote stokers to the responsibility of watchkeeping.

Of the 30,000 stokers in the Navy many are no doubt estimable men, but the qualification for entry is no guarantee of their capability. They come from the plough or from the street, many of them, because they find no other opening for the utilization of their physical qualities. One might almost say, indeed, that the work is so arduous and so unattractive that it is accepted only as a last resource. For this very reason those who rise above their environment in the stokehold in respect of moral courage and intelligence ought to have incentive to advance. Merit in all circumstances of life ought to have its reward, and this reward should almost be proportioned according to the degree of discouragement afforded by environment. It is therefore only fitting that the stoker should rise, not only to a position of comparative responsibility among his fellows, but to warrant rank. But such reward must always be subservient to the dominant consideration in any service; it must never jeopardize the continuance of general efficiency. It is on this point that we take exception to the method of the Admiralty, in so far as it is directed towards the encouragement of the stoker.

It is true that when the stoker, after the display of commendable qualities, is selected for advancement to the rank of mechanician, he has to undergo a two years' training; but before he has reached this stage he has attained the age of at least twenty-five years. We do not propose to enter into the question as to the adaptability of men who have reached this period of life, but the degree of adaptability must be more or less influenced by the earlier training. No doubt men whose mental qualities have been cultivated to a more or less high degree in early life have been known to develop in later years high qualities in some department of science and learning generally, of which they were more or less ignorant at thirty or forty years of age. But the case is different with the stoker,

as his mental faculties are, to begin with, more or less undeveloped. In any case, two years' training is quite inadequate to qualify him for the responsibilities of watchkeeping. The training is directed to the use of tools and to some superficial knowledge of the theory and practice of mechanics. We take the definition of the First Lord of the Admiralty as to the aim in view in the two years' training. These mechanicians were all given, it was stated in the House of Commons a few months ago, "a slight training—not that of a skilled artisan—in mechanical work, to enable them to understand the general run of the engine which they will be called upon to drive." To an engineer hardly anything more need be said to establish the inadequacy of the training, but we should like to influence those responsible for this conception of the duties of a watchkeeper. Apart altogether from the insufficiency of the period, there is the fact that this training is to be by the engine-room artificers, who regard the new scheme with disfavor, because they consider that from several points of view it robs them not only of their most interesting function, but also of the fullest measure of advancement in the service. In such circumstances it is only in accordance with one of the weaknesses of human nature that they should not be particularly enthusiastic about the prospective mechanician acquiring the fullest practical knowledge. Again, almost every sense has to be cultivated in order that trouble may be scented before it arises; hot bearings, loose bolts, water-hammer, and slight inequalities in running may be discerned by the engineer who is familiar with the engine-room atmosphere, and such familiarity is not achieved even in a couple of years. It is not enough to know that an engine has broken down; in action an engine must not break down; vigilance alone can ensure the avoidance of trouble, and in the "general run of an engine," as the First Lord puts it, there is more than the mere touching of a button and leaving the steam to do the rest.

Resource is the most important quality in life, whether in the engine room of a war ship or in the admiral's cabin, and such resource must be developed through long and intimate

experience of conditions, even remotely possible. The other day a battleship was steaming into port, when a key, becoming loose, rendered inoperative the wheel of the starting gear, with the consequence that the starting-engine shaft could not be utilized for reversing or stopping the engine. The engine and its propeller were thus apparently beyond control. Such an accident in maneuvers might have involved the loss by collision of two ships, in war tactics the loss of the engagement, or, perhaps, even the loss of our sea supremacy, always provided that the resource of the watchkeeping engineer was not sufficient to instantly avail himself of an alternative. As a matter of fact, the engineer officer on this particular occasion at once manipulated the throttle valve of the engine, and so brought the vessel to anchor without any one on the bridge being conscious of the danger. Other similar contingencies might be instanced, which must arise, especially in war service, where the changes in speed involved by quick tactical movement must be numerous, and therefore must tend to excitement on the part of the watchkeeping engineer who is not thoroughly familiar with his work. Many instances of danger through insufficient knowledge could similarly be quoted. Quite recently a mechanician, sent to manipulate a duplex bilge valve, failed to understand its operation, and succeeded in flooding the engine room in a marvellously short period of time, with the result that the vessel had to be docked. Such a maladroit proceeding in the course of an action would be very serious.

Apart, however, from the question as to whether or not stokers can acquire the knowledge and experience requisite for efficient watchkeeping, there seems even an objection to the constituting of a new rating in order to separate engine driving from engine repairing on board ship. We have more than once pointed to the great advantage of the engine driver being, wherever possible, responsible for engine repairing. It stands to reason that artificers, when responsible for the driving of the machinery, will more correctly diagnose the necessities of repair, and will take a deeper and more direct interest

in maintaining the efficiency of the machinery. On the other hand, when they are conscious that the watchkeeping is done by men of less practical experience, and of not greater, if as much, professional knowledge, their interest will be diminished. There is, no doubt, the question of *esprit de corps* and discipline, but when the claims of these are contrary to the inevitable laws of human nature it is too much to expect absolute compliance, except under immediate control. Any one who keeps a motor car knows perfectly well that where the chauffeur is a mechanic and is responsible for the repair work, greater care is exercised in obviating breakdowns, with the result that the repair cost is considerably less. When the chauffeur knows that his employer's good will, sometimes expressed in a premium or in increased wage, is dependent on the maintenance of the car in satisfactory condition, he is keener to note any tendency towards breakdown, and to obviate it by precautionary measures. The same applies to the naval machinery on board ship, where the artificer obtained his promotion to the rank of artificer-engineer as the result of freedom from breakdowns rather than facility in repair. It will be always difficult with two ratings, responsible separately for running and for small repairs, to apportion the credit or blame, and from this point of view the change cannot give the best results.

There is the further consideration of the relative status of the artificer and mechanician. The repairer must take his directions from the watchkeeping engineer, and there can be no question that, notwithstanding the smattering of elementary science and practical and applied mechanics to be instilled into the stoker while he is being transformed into a mechanician, he will, in the great majority of instances, fail to come up to the intellectual standard of the thoroughly-trained artificer. Moreover, in the smaller craft, which bulks so largely in the Navy List, members of the artificer class are often now entirely responsible for the working of machinery, there being no engineering officer in the complement, and this prize of the

artificer is now presumably to pass to the mechanician, a change which cannot be for the benefit of the service.

We do not propose to enter further into the personal question. The stoker, as we have said, has claims to advancement; but, as was pointed out by our correspondent, "An Old Engine-Room Watch-Keeper," in last week's issue, and by another correspondent in his letter this week, there are other avenues for recognizing these claims. It might even be possible for a stoker to serve a full apprenticeship and acquire adequate experience to become an artificer. Into that question we do not propose to enter. It is enough to consider the effect of the new machanician on the maintenance of the machinery of the Navy in a reliable condition, particularly in war times. There is the suspicion that many in authority are conscious of the insufficiency of the mechanician's training. Were mechanicians displaced by artificers in the *Indomitable* before she left on her remarkable voyage to Canada last summer; and, if so, what was the explanation? Is it also the fact that in the complements of many ships two mechanicians take the place of one artificer? If so, is the cost to the nation not greatly increased, apart altogether from the fact that artificers are taught, at their own expense in private works before entering the service, while the training of the mechanician involves very considerable expense to the nation? Moreover, while on this question of economy, we may ask, is the repair work for the artificer sufficient to keep him employed while the ship is at sea? and, if not, how is his time utilized?—" Engineering."

DOCKYARD ADMINISTRATION.

By a Correspondent.

Before we attempt anything in the nature of a comprehensive survey of the present-day organization of the Royal Dockyards it is desirable, even at the risk of being somewhat elementary, to refer to the principal functions these establishments are designed to fulfil. The main features of their rôle

may be differentiated under the three heads of (*a*) construction, (*b*) maintenance, (*c*) repair and refit work. The two latter conditions are to some extent interchangeable, but not necessarily always so. With regard to (*a*), although it is placed first on the list, there are many competent critics who hold that it is not the most important part of dockyard work.

Down to within ten years ago it is no exaggeration to say that the administrative organization of the Royal Dockyards was in many respects little better than crude. The true principles of decentralization did not appear to be understood; at all events, they were certainly not applied. In comparison with the private contract yards of the kingdom, the Government establishments showed to unmistakable disadvantage. No study was made of the economic application of labor, with the inevitable result that it was impossible to measure work by such a low standard of cost as the private firms attained. The plant was old-fashioned and obsolescent in many details, thus imposing an additional handicap upon economic productivity. Furthermore, the system of placing contracts left much to be desired, as it is the easier now to realize in looking back by the light of present-day methods.

Although improvement was always steadily in progress, the real wave of dockyard reform came at the close of the Russo-Japanese war. It seemed as though the Admiralty, heedful of the immense advantage which the resources of renewal and repair indubitably conferred upon the Japanese, resolved to set their own house in order in this respect. The reconstitution of the dockyards upon a war footing was the keynote to the long series of changes which was then entered upon—but gradually, so as not to bring about any dislocation in the continuity of routine. It was recognized that a great advantage might be gained by co-ordinating the methods of the private shipyards of the kingdom, which are primarily run to pay, with the principles of Admiralty policy as far as possible. The superintendent officers of the day were granted leave to make tours of inspection amongst the great firms of the North, and were invited to exercise their initiative in the direction of rec-

ommendations. It would be too lengthy a retrospect to trace the gradual evolution set up by this new policy to its current phase of development. Suffice it to indicate one conclusive proof of the remarkable enhancement of economic efficiency which followed. Between the years 1904 and 1906 it was found practicable to reduce the dockyard establishment by 3,000 ratings without any resultant diminution in the volume and course of the work. The actual figures given in the Navy Estimates for the respective years named are 32,823 established and hired men, and 29,821 established and hired men. Since the financial year of 1905-6 there has been a steady natural process of expansion in the total of the personnel employed in the Royal Dockyards.

Construction has been placed first on the list in the foregoing brief résumé of dockyard functions, and, therefore, without necessarily implying that it is either the chief or most important function of these Royal establishments, we will deal with it first. And here it becomes necessary to draw a broad differentiation at the very outset. For warship construction, in the dockyard signification of the term, means nothing more nor less than the labor of rearing. Of every million pounds sterling expended upon a dockyard-built warship but one-fifth is actually expended in the dockyard. These Government establishments are mere assembling depots, and in no sense manufactories.

It is opportune to refer at this point to the discrepancy which frequently exists between the cost of a dockyard-built warship and a privately-constructed vessel of the same class. In the largest proportion of these comparisons the factor of economic production is on the side of the privately-built ship. But at the same time, there are quite enough examples on the other side of the account to render it clear that no invariable rule exists in the matter. Various elastic administrative conditions will affect the completed cost of a warship—which figures are often very divergent from estimated cost—chief amongst which must rank the successful placing of sub-contracts, and differences in the labor camps. The dockyards, doubtless, en-

joy more even continuity of labor conditions than do the private yards, but it is a question whether this is a wholly unmixed advantage, inasmuch as it is apt to engender a tendency to relax the concert pitch of production, and thus to fail to secure to the taxpayers the fullest attainable measure of return for the expenditure incurred. As we had occasion to remark a little further back, this quality was very much more prevalent a few years since than it is today, and improvement is still always in progress. The shortening of the time limit for the completion of a warship has had much to do with effecting this result. The ships of the pre-*King Edward* class were seldom finished much under three years. Now the 19,000-ton battleships of the improved *Dreadnought* type have to be completed within two years from the date of laying the keel plates, and this on normal labor as far as possible, *e.g.*, without recourse to overtime or night shifts. It is too early as yet to forecast what the actual effect of this will be in bringing about greater approximation between dockyard cost and shipyard cost of warship production, because the only available comparison thus far—the *Temeraire, Bellerophon* and *Superb*—has been largely nullified by the labor troubles in the North and Midlands, which have occasioned several months' delay in the delivery of the dockyard ships.

The conditions of labor in the Royal yards, as has been said, are now organized largely upon the lines followed in the private contract establishments of the kingdom. But the method of financial administration remains a severe handicap to the attainment of the highest degree of economic productivity. The system is too cut-and-dried; taking a regular preconceived flow of work as a basis for computation, and allowing a wholly insufficient margin for expansion or contraction in the normal routine. Therefore, if a big armored ship is suddenly and quite unexpectedly thrown upon dockyard hands for extensive refit as a result, let us say, of some serious mishap, dislocation of financial continuity is the consequence. The constructive manager demands an expenditure of £30,000 or £40,000, and the Admiral-Superintendent has to plot and plan to work this

out of the weekly wages bill in the best way he can devise, for the Admiralty are sturidly obdurate in their opposition to supplementary dockyard expenditure. Of course, the big armored warship gets her extensive refit, for there are the men and there is the plant necessary to carry it out. But other work which had been previously provided for when the Estimates were passed has had to be hung up in consequence, and we get the extravagant system of "stand by" jobs developing out of necessary work, of which striking instances have been furnished in the not very distant past by the belated cruiser *Encounter* at Devonport, and the still more belated cruiser *Europa* at Portsmouth. Private contract work on such lines would be a commercially impossible proposition.

Still, progress continues to move steadily in the right direction, and possibly it is better that reform should not be too drastic nor too hasty lest it should abruptly dislocate the conditions it seeks to amend. Present-day policy aims at maintaining the Royal Dockyards in a position to lay down one first-class capital ship per annum, and to complete the same within two years, and to keep pace with the necessary repairs and refits of the fleet.

It has been a matter of regret to more than one Admiral-Superintendent that there should not be more professional affinity between the Royal Navy and the dockyards. This regret has no reference whatever to any question of relative status. There is such a big civilian element in a dockyard staff that no sort of conflict can reasonably exist. But where the difficulty has always lain—and, in diminished degree, still lies—*is in the lack of co-operation between the active service and the dockyard.* There is too little of the spirit of working together for the atttainment of the highest economic efficiency. When a warship comes into dockyard hands her commanding officer, from instinct or tradition, is for leaving everything to the "maties." Such a posture of affairs may not seem a matter of first-rate importance on the face of it; in reality it in the aggregate militates against the smooth tenor of administrative efficiency.

Whilst the relative value of construction *versus* repair and refit work in peace time may be debatable, the more important use of the Royal Dockyards in war time is beyond question. These would at once become recuperating havens, to make good as effectually and as expeditiously as possible the injuries of battle. To maintain the fleet at sea is the primary business of the Government yards, and the current administrative policy of these establishments is based upon a clear perception of this fact. The great growth in the dimensions of capital ships is a factor that has brought in its wake a difficulty not perhaps sufficiently appreciated by the Naval Construction Board, which is only concerned in getting the fullest measure of fighting value out of a given total of displacement. Portsmouth and Chatham can only drydock one *Dreadnought* apiece, and Devonport, with all the resources of the new Keyham extensions, can manage to dock three *Dreadnoughts*. If the position could be reversed, and Chatham exchange facilities with Devonport, it would be more in keeping with the strategic hypothesis upon which our naval dispositions are now based.

In this connection we are brought to another important and interesting point. How far does the present degree of productivity and the rate of dealing with the average defect lists in the Royal Dockyards represent the ratio of their full capacity under the strenuous pressure of warfare?

The question is one which can only be answered in qualified degree; but, even so, it is fraught with instructive conclusions. The Royal Dockyards have never been called upon to stand the strain of war since the advent of steam and steel. The nearest approach to any such tax upon their powers was during the Fashoda crisis. The personnel of Devonport, Portsmouth and Chatham toiled night and day for a fortnight, and accomplished prodigies of preparation. They were working upon very different material from what they would have to handle today, and with more limited resources.

A Fashoda panic today would find the dockyards in a very different posture for dealing with the sudden enormous increase of pressure. The old Fleet Reserve—the despair of a

generation of admirals-superintendent—has gone. The nucleus-manned divisions of the Home Fleet are an integral naval force, and not a dockyard force at all. On a war mobilization they would be completed to full complements from the naval depots of their respective ports without throwing the smallest appreciable burden upon the dockyards. The Special-Service Divisions, popularly known as the Baltic Fleet, and regarded as the final line of reserve, would require dockyard co-operation to prepare for sea; but as the ships composing these squadrons are maintained by their skeleton crews in a very respectable state of efficiency, the work of preparation would consist rather of coaling, victualling, completing with warlike stores and the drafting of reserve complements, than of refitting and repairing.

The Dockyard Reserve nowadays has been narrowed down to vessels which are in dockyard hands either for completion or for extensive refit. When a new warship is launched from the Government slips, or delivered for Admiralty acceptance trials by private contractors, she is placed in the Dockyard Reserve, and remains there until commissioned. Of course, the largest proportion of the Dockyard Reserve is made up of vessels which have been paid-off out of commission in order to allow of structural alterations or renovation, and it would undoubtedly be the primary business of the Government establishments in the event of war to push forward this work with all possible despatch.

Coming back then to our question as to what may be regarded as the maximum capacity of the Royal Dockyards in output and fleet maintenance during a conflict, if the labor conditions were expanded to the full limits of the accommodation of these establishments, they should be able to keep pace with the current of damage sustained by our squadrons in all but such decisive battles as would probably determine the final issue of a war. The three main dockyards can drydock five of the biggest capital ships, some half-dozen lesser first-class armored ships, and, roughly speaking, about a score of smaller units at one and the same time. Devonport can have two, and Ports-

mouth, Chatham and Pembroke one capital ship apiece upon the slips at one time; and as in normal times a *Dreadnought* type of battleship can be reared to the launching stage within ten months, this same number of keels could be laid down annually. Of course, this is reckoning with confidence upon the adequacy of the private contractors to maintain the supply of plates, armor, rivets, engines, boilers and guns, without which the dockyards cannot possibly continue to fulfil their part as building establishments.

Here we have what may be regarded as a categorical summary of the limitations of dockyard productivity in the present stage of development of these organizations. When the routine of full expansion on a war footing is reached we have a possible annual output of five capital ships, which may be supplemented by three light cruisers, of the *Boadicea* type, and a small group of destroyers and submarines. We have dry docking resources for five *Dreadnought* battleships, as many *Duncans,* or vessels of approximate dimensions, and a score of small cruisers, scouts and destroyers. But all warships are not necessarily damaged below the water line when they come in to refit after a battle, and for the accommodation of those vessels which have been injured in their topworks there are basins, quays and wharves enough within the precincts of the three principal dockyards to take one-half of the British Fleet.

Within the limits of this article it has not been attempted to do more than take a general superficial survey of current dockyard administration. As a result of such a survey we are led to the conclusion that: (1) the reorganization of labor conditions which has slowly developed during the past five years has been accompanied by enhanced production and greater economy; (2) that whilst considerable progress has been made, there is still necessity for improvement in the methods of financial control, allowing to the admirals-superintendent more initiative in the dovetailing of all the productive features in the great industrial fabric with a view to getting better value for expenditure by more freedom to expand or contract the weekly wages bill, so that the annual estimated total remains

the same; (3) that whilst the experiment of a central estimating office has been in a measure satisfactory, the whole system of dockyard estimating needs reforming. Under present conditions, when a warship is due for big refit, each head of department estimates for the work that falls to his share. The result is a sort of general competition, in which each chief is anxious to do the very best he can for his own department. As a consequence, the estimated cost always leaves a very fair margin over and above the real anticipated cost, so that a department shall not be on the wrong side when the charges and expenses accounts come to be written up. When the estimates are passed there is no incentive to save any surplus provided for, and, on the contrary, a strong inducement to spend the whole amount, so as to escape any implied reproach of extravagance in estimating.

But the most efficient organization must needs have their flaws, and it is a faithless form either of criticism or appreciation which ignores or minimizes these. When we compare the state of the Royal Dockyards today with what they were even a decade ago, the transformation is little short of remarkable. Because it has taken the somewhat impalpable form of principle and method, rather than the obvious shape of great material changes, the full extent of this progress is not understood by the public at large. But the result is the same. In 1898 the Royal Dockyards were but indifferently organized building and repair establishments run at great relative cost. Today they are, in the fullest sense of the term, naval arsenals on an efficient war basis.—"The Engineer."

THE CRISIS IN THE FRENCH MARINE.

For many years past the French Navy has been an object of trenchant criticism both in and out of Parliament, and the attacks have at times been of so violent a character that they lost much of their force because the public deemed them exaggerated by political bias. Nevertheless, it was impossible to

deny that the situation of the Navy was far from satisfactory. As early as 1894 a Parliamentary Commission was appointed to make an inquiry into its condition, and was followed by another Commission in 1904, but these investigations do not appear to have had any really practical results. The blowing up of the *Jena* called for a further Commission of Inquiry in 1907, when some very interesting evidence was taken, and from that moment dated the public agitations for reforms which culminated in the appointment of M. Alfred Picard as Minister of the Marine. The fact that in the course of two decades France has fallen from her position as second naval Power to the fourth or fifth place was sufficient to cause serious alarm, which was all the more justified in view of the fact that the country was spending enormous sums to keep the Navy in fighting trim. Obviously there was bad management and a criminal waste of public money. As a guarantee that the Navy funds are utilized in a proper manner, the accounts are audited annually by a financial Commission; but as a matter of fact the reports of this Commission have rarely erred on the side of severity. All this was changed when M. Alfred Picard took the naval department in hand. The financial Commission picked the accounts to pieces with relentless logic. The prices paid for material were compared to show that enormous differences existed in the cost of shipbuilding material, stores, fuel, provisions and the like obtained from different firms on the same dates. The large sums paid for palms and cut flowers to adorn the office and apartments of the former Minister of the Marine were cited to show that an example of economy was not set by quarters where it might have been most expected.

What the public look forward to with special interest, however, was the inventory of the marine undertaken by M. Picard himself. Before suggesting what was to be done the new minister took a minute stock of everything, of the ships and their equipment, stores and reserves of ammunition, the ports and arsenals, and their capabilities in the way of building and repairs. When this was completed the report showed that the

Navy, as a fighting combination, could hardly be said to exist. All that could be said was that there were the elements of a navy consisting of ships that only had one half of their guns, of arsenals entirely devoid of reserves of ammunition, and of ports that did not provide shelter for ships in time of war, and were not properly equipped for drydocking and repairing. As a first step in his program of reorganization M. Picard insisted that all these shortcomings should be made good. It would mean a further heavy sacrifice to the country, but it could not be avoided if the Navy were to be something more than a name. The minimum that could be done was to complete the armament of warships and increase the reserves of explosives, improve the equipment of ports to allow of their sheltering, drydocking and repairing ships existing or under construction, and ensuring the prompt mobilization of the fleet; to hasten the construction of ships on the stocks, as well as the carrying out of alterations to ships afloat, such as the partial suppression of heavy and conspicuous upper works and the installation of refrigerating machinery in the powder magazines, and to augment the quantity of material in stock for naval constructions. The existing fleet had to be put into as high a state of efficiency as possible before any further proposals could be entertained for spending money upon the building of new units.

The seriousness of the situation was emphasized not so much by what was revealed by M. Picard's report as by what it concealed. If the Navy had been allowed to deteriorate to such an alarming extent it was desirable to ascertain who were responsible for this state of things. On the proposition of M. Delcassé, a Parliamentary Commission of Inquiry was appointed to go into the whole matter, and during the past two or three months it has been collecting at Toulon, Brest and other places, evidence which displays negligence that can only be characterized as criminal. In addition to this, the system of red tape has been developed to such an extraordinary extent in the marine department that months expire before the smallest requirement is executed. Instances are given of requests for

small articles costing only a few pence being passed from one department to another, necessitating a considerable amount of clerical work, and finally costing enormously more than the value of the articles. A typical example of waste resulting from an utter want of initiative is afforded in the case of a cruiser in Toulon, which required a bamboo wireless telegraph mast. Instead of getting the bamboo at home, the marine department ordered it from Indo-China, but before it could reach Toulon the cruiser had left for Saïgon. The idea of utilizing the bamboo mast for another ship apparently did not occur to the administration. It had been ordered for this particular cruiser, and the cruiser must have it. Consequently, the bamboo followed the cruiser to Saïgon, where obviously one could easily have been procured at small expense. Again, Saïgon required a few gallons of oil that could have been bought from any local merchant. It preferred to telegraph to Toulon, which forwarded the oil at a cost of more than ten times its value. Another instance of the inconveniences of red tape was afforded in an order sent to the marine department by the Admiralty of Algiers for a fixed boiler. For two years nothing more was heard of it, and when the belated boiler arrived it did not conform to the specification, and could not be used. Examples like this could be multiplied, but one more must suffice. The new battleship *Démocratie* left Toulon to carry out firing trials. It was then discovered that the gun sights were without springs, and the battleship had to return to Toulon. A search in the arsenal revealed the fact that there were no such springs in stock, and they had to be ordered from a local watchmaker, who took four days to make them, during which time the battleship lay idle in the port, waiting for an article that cost about five shillings. In order to put an end to the waste and delay due to superfluous clerical work M. Picard has given instructions that all books not strictly necessary to the proper working of the department are to be suppressed. This is not the least meritorious of his reforms. Until now the Navy has been strangled by red tape, and this simplifying of the clerical work will enable it to develop

normally under the improved organization of the entire department.

If red tapeism is responsible for much of the demoralization of the French marine, it is evident that the Commission of Inquiry had to look somewhere else for the shortcomings that were revealed during the visit to the Toulon arsenal. It was found that there were not sufficient reserves of ammunition to last for an hour's fighting. This was publicly stated a few months ago by the Commander of the Mediterranean Squadron, who, for communicating his views to the press without the consent of the minister, was relieved of his command. The inquiry, however, completely confirmed this sensational statement, and it is certain that had hostilities been declared at any time during the past year the French fleet would have been almost immediately reduced to a state of helplessness. At Brest it was discovered that a number of obsolete ships were kept in reserve with their full complement of crews, who were thus deprived of the training that would have been invaluable to them. When investigating the conditions under which vessels were constructed there was observable the same absence of good management and foresight. Not only was there an inexplicable discrepancy in the costs of material, but the building of ships was considerably delayed because orders for engines, boilers and shipbuilding material were not given out simultaneously. It is true that in the case of boilers orders have frequently been delayed pending debates in the Chamber of Deputies, so that Parliament is not without some responsibility for the delays as well as for the changes of design which have been carried out to battleships under construction. The Minister, the Conseil Supérieur de la Marine and naval architects have all been adverse to taking any initiative, unless what they do is entirely approved of by Parliament.

It is not too much to say that parliamentary control, with its conflicting views on every possible subject concerning the Navy, has done much to destroy any continuity of ideas in the building up of the marine. It has run through the whole gamut of commerce destroyers, torpedo boats, submarines

and, finally, battleships of the *Dreadnought* type, in a way that may reasonably be put forward as an excuse for the absence of settled policy which has characterized the naval administration for many years past. Further difficulties have arisen from the condition imposed upon the marine of purchasing all its material at home. To take the case of turbines for the new battleships, the firm constructing them had to lay down a costly plant, the depreciation of which must be set solely against the orders under execution, because the firm are not sure they will get any more. Thus a far higher sum has to be paid for these turbines than if they were purchased abroad. Until the battleship *Danton* was completed with its turbine machinery there was no large vessel in France fitted with turbines, except one in the merchant service, and thus the equipment of the new battleships of the *Dreadnought* class with turbines is regarded as of an experimental character, although, of course, there is plenty of justification for launching out upon the construction of turbine battleships by the increasing employment of these engines in the British and German navies. Nevertheless, the evidence of the engineers of the *Danton,* taken during the inquiry, was not quite so favorable as had been expected, the main objection being the old difficulty of reversing. This does not imply that there is any doubt in the minds of French naval engineers that the turbine is superior to the reciprocating engine for battleships, but with the limited experience so far obtained it must be admitted that they show a somewhat qualified approval of the new propelling machinery.

The inquiry also turned largely upon the question of fuel contracts, where the discrepancies in prices are perhaps larger than for other material, and it has long been urged that the practice of Government, in limiting the tenders to a few firms, tends to create a monopoly which enables the coal owners and manufacturers to obtain high prices. Justification of this policy is urged alike on behalf of the Government and of the manufacturers, the latter declaring that they are obliged to make allowance for the procrastination of the marine in pay-

ing for its fuel and material, while the naval department argues that it is obliged to restrict tenders to firms who are capable of supplying the most suitable coal and the best material. One of the principal complaints made in Parliament has been the excessive price paid for boilers, and the naval department has often been urged to extend tenders to boiler firms other than the two or three who at present have a monopoly of this business. While this plea may appear sound enough from a financial point of view, it is not regarded with favor by naval engineers, who naturally consider that the types of boilers employed should be restricted as far as possible. The fewer the types the better for the training of engineers and stokers, as well as, of course, for repairs, and the keeping of the generators in a high state of efficiency. It is probable that as the result of this inquiry the Chamber of Deputies will see the wisdom of abstaining from agitating about technical matters of which it has no knowledge. At all events, it may be presumed that Parliament will henceforth allow the naval department to deal with the question of boilers in the way it thinks best.

It is impossible to deal here, except in a very summary manner, with the various matters arising out of the investigation. Much might be said about the guns mounted on recent battleships, which are already coming in for severe criticism. The failure of a gun on the testing ground at Gavres, and again on board the *République,* suggests to many experts that the high muzzle velocities now adopted by the French artillery are detrimental to the life of the gun. Doubts are also being expressed concerning the shells, and the forthcoming bombardment of the *Jena* is being awaited with considerable interest, as it is understood that the final type of shell to be adopted by the French Navy will not be settled until after these experiments. It is certain that, with their high muzzle velocities and the new P explosive, which is reported to have given extraordinary results, the French possess a powerful artillery, but the point to be demonstrated is the reliability of the guns and shells.

While all departments of the marine have come in more or less for severe strictures, one of the most serious complaints put forward has reference to the defective material supplied by certain private firms. Considerable prominence has been given to this matter by the action which M. Picard is alleged to have brought against Creusot for supplying turrets in which defective parts have been repaired by oxy-acetylene welding. So far as the oxy-acetylene process is concerned, it has, of course, been abundantly proved that a piece properly repaired by this method is as strong as if it had never developed fault. The claim made against Creusot, however, is to the effect that the firm delivered material in which a defect had been repaired by oxy-acetylene welding after a similar piece, treated in the same way, had been rejected. Creusot urges that it did nothing of the sort, and thus the matter stands pending the action. It almost appears as if this action had been taken, not so much with a view to giving a salutary lesson to firms who contract to supply the Government with material, as of impressing the public with the idea that Government intends in future to take strong measures for the protection of its interests. The department itself is not entirely above reproach. Much of the material supplied for one of the submarines constructed in the Toulon arsenal was found to be defective, and there were so many mistakes in the plans that the assembling of the parts entailed considerable extra cost. Serious charges have been laid against certain officials of accepting material that had previously been rejected, and as the matter will probably come up in the law courts it is expected that the inquiry will result in a plentiful crop of scandals.

The Government has undoubtedly done well to probe the source of the country's naval decline. A policy of concealment is not to be commended in a country like France, where the administrations are notoriously lacking in energy and initiative. Having revealed the shortcomings, painful though they may be to the patriotism of the French, the country knows what is to be done, and will certainly make the sacrifices necessary to remedy the errors of the past. M. Alfred Picard is

aware that he has public opinion behind him, and he will obtain every support in the accomplishment of the task he has undertaken to put the Navy in its old state of efficiency.—"The Engineer."

THE REPORT ON THE FRENCH MARINE.

The report that has just been issued by the Parliamentary Commission of Inquiry under the Presidency of M. Delcassé confirms on every point the lamentable shortcomings in the French Marine which have been revealed by the inquiry that has been proceeding for the past four months. Rarely has an official document been so incisive in its condemnation of a public service as the report prepared on behalf of the Commission by M. Michel. The reasons that have brought about the existing state of things, and temporarily deprived France of her position as a naval Power, are clearly set forth, and it becomes evident that while a want of proper organization is mainly responsible for the decline of the Marine, much is also due to the Socialist "reforms" of a former Minister whose attempts at leveling down everything had merely the effect of destroying discipline, order and influence. Taking first the cost of construction, M. Michel points out that the plans of battleships were never completed by the time orders were given out. The plans of the *Justice* were altered fourteen times after this vessel was put on the stocks, and the same might be said of the other battleships and cruisers, while the contracts for the material required for the ships authorized by the program of 1906 were given out before any decision had been come to as to the design of the turrets and the types of boilers. For battleships of the *Danton* class the original estimate of 220,000,000f. was exceeded by 100,000,000f., mainly on account of the continued changes to plans.

Much has already been said concerning the alleged action of firms in combining to uphold prices for material supplied to the Marine. Although there may certainly be some ground for this, engineering firms having always pleaded justification be-

cause the State is a hard taskmaster, and delays payment as much as possible, the Commission has come to the conclusion that prices all round have considerably increased, notably as regards armor plates, turrets and engines, while the cost of turbines appears particularly high. In this latter case the high prices asked are undoubtedly due to the fact that the firms who lay down plant for the manufacture of turbines, especially for the Marine, have to allow a considerable amount for depreciation, because, for the moment at any rate, the business being done in turbines is very small. Another reason for the high cost of construction is to be found in the low efficiency of the arsenals, which may be attributed to the obsolete machinery employed and also to the suppression of piece work. This was one of the "reforms" carried out by M. Pelletan, who introduced the Socialist principle of leveling down everything and reducing the hours of work, while at the same time foremen and engineers were practically deprived of all authority over the men. As a means of remedying this state of things the Commission invites the Chamber of Deputies to refuse permission to construct any vessel in the future until the plans are practically complete and arrangements are advanced for giving out orders. So far as concerns the high cost of material the Commission is of the opinion that the steady increase in prices is due to the fact that the Marine Department does not look sufficiently after its interests, while, by its unnecessary exactions, it compels manufacturers to provide for contingencies that do not exist with ordinary contracts. Consequently the Commission is of the opinion that the Marine Department should suppress clauses in contracts that are not really necessary, and every other method should be adopted to secure a reduction in prices. The conclusion of the Commission as regards the arsenals is that they are not at present in a state to carry out rapidly the work of construction and repairs, that the plant is insufficient and out of date, that piece work should be generally adopted, that in cases where the character of the work does not allow of the introduction of piece work the men should be paid wages equivalent to those paid to men

employed in other departments upon piece work, that the foremen should be invested with greater authority, and that work should only be given outside when it is found impossible to undertake it in the arsenals.

The question of boilers has, perhaps, attracted more attention than any other when discussing the cost of building battleships. While Parliament has always advocated increasing the number of boiler firms from whom tenders are received, the Naval Department has preferred to limit the types of boilers to two, with the object of unifying the steam-generating equipment and facilitating the training of stokers; but it is argued that any advantage obtained by uniformity of boilers is lost by the high prices that have to be paid to firms who look upon the business as a monopoly. The Commission inclines to this latter point of view. It regrets that during the past ten years the Ministers of Marine have failed to utilize competition as a means of reducing prices and securing an improvement in boilers which are generally recognized as the best; that the Minister, after obtaining from the Technical Committee a list of boiler firms from whom tenders could be invited for the nine battleships and armored cruisers under construction, ordered them from two firms on the list without inviting tenders from the others, notwithstanding that the boilers so ordered were not the types unanimously approved of by naval officers and marine engineers. Consequently the Commission recommends that in future tenders for boilers shall always be invited from firms approved of by the Technical Committee. The manufacture and storage of explosives are to be subjected to a much more rigorous supervision, and this supervision is to be assisted by naval officers who are to prepare themselves for the task by undergoing a period of instruction in the powder factories. The armament of battleships comes in for severe strictures from the Commission. It states that the four divisions of battleships and the division of armored cruisers in the Mediterranean have not their full supplies of steel shells; that the division of armored cruisers forming part of the Northern Squadron have only a third of their supplies; that neither for

the Mediterranean nor the Northern Squadrons are there any reserves of steel shells, despite the fact that the types of shells were fixed upon as early as 1905 and 1906; that the type of shell for battleships of the *Danton* class was only settled upon at the end of February last, so that it is a practical impossibility to have them manufactured by the time the *Danton* is ready for service at the end of next year. The Budget estimates have, in fact, made no provision for the manufacture of these shells. The Commission blames this "want of foresight," and urges that it should be remedied without delay. The same absence of foresight is observable in the harbor works. The law of 1901 authorizing the building of drydocks and basins has been utterly ignored. These should have been completed in 1909, but nothing has been done. No one has even thought of the necessity of building drydocks to take battleships of the *Danton* class. Nor is there sufficient provision for the storage of coal. When it is observed how much has not been done it may reasonably be asked what has become of the enormous sums of money voted for the carrying out of these works. The former Ministers are blamed for this state of things, as well as most of the other shortcomings, and they are likely to have anything but a pleasant time when they are called upon to defend themselves in the Chamber of Deputies. The general organization of the marine, or rather the want of it, is summed up in the statement that "between the different services of the central administration there is no unity of views, no systematic effort, no method and no defined responsibility. There is too often negligence, disorder and confusion."

This report effectually clears the way for the reforms in the organization of the marine which the country is determined to carry out. And it will prove a formidable undertaking. There is enough in the Commission's recommendations to occupy attention for a considerable time, but it covers much of the ground previously gone over by M. Picard, whose proposals are for the most part merely emphasized, and the report will certainly have the effect of inducing the Chamber of

Deputies immediately to vote the sums required by the Minister for doing what he claims to be an absolute minimum to put the Navy on something like a satisfactory basis. The Commission has, moreover, shown the necessity of undertaking work which M. Picard was obliged to leave in the background for fear of frightening the country over the expenditure that would have to be incurred. The Commission, on the other hand, does not hesitate to make the most of the situation, and it is highly probable that the Chamber of Deputies will be induced to vote more than is asked for in order to clear up arrears of work in the way of harbor improvements, stocks of explosives and shells, and the equipment of existing ships as soon as possible. Until this is accomplished, and it is likely to occupy some years, it is difficult to see what can be done with the new shipbuilding program beyond preparing plans and advancing preliminaries, so as to push forward the construction as soon as funds are available. Unfortunately, the Government is committed to such a huge expenditure in other directions that fresh sources of revenue will have to be found before the new shipbuilding program can be started upon, and this will probably be one of the questions discussed in the forthcoming debate upon the development of the Navy.—"The Engineer."

THE STATUS OF THE WATER-TUBE BOILER.

Several years have elapsed since the question of the adaptability of water-tube boilers to naval purposes was one of the crucial questions of the day in the engineering world. The reports of the Boiler Committee were made just about the period when attention was first being diverted from the stokehold, over which bitter contention had reigned for six or seven years, to the engine room, where the type of propelling machinery that should be adopted was the cause of sufficient controversy completely to overshadow the equally important essentials of boiler-room equipment, and since then the boiler question has been largely allowed to lapse. But although it has

not attracted public attention to the same extent as has the introduction of the marine turbine, very solid progress has been made in water-tube boiler design, to the great advantage of the naval service. Quietly and without ostentation the Admiralty engineering staff has eliminted the inferior features of the multitude of types from which choice could be made ten years ago, and in the process has narrowed down to two types the boilers used in his Majesty's Navy. The types with excessively bent tubes or with bends of absurdly small radii, and those replete with screwed joints or other expensive systems of tube attachments, have all disappeared, and there remain now only the Babcock & Wilcox among the large horizontal-tube types, and that of Mr. Yarrow, whose well known simple straight-tube triangular type has never varied in essentials from the time of its application to H. M. S. *Hornet*. A modification of the triangular Yarrow system has more recently been introduced by the White-Forster patentees, in which all the tubes are curved to the same radius, like the staves in a barrel, and are so arranged in the boiler that, while obtaining the advantage of a predetermined direction of motion when expansion due to heat occurs, they are also so arranged that any one tube can be cut out or replaced without touching any other.

Boilers of the Thornycroft, Normand, Reed or Blechynden type have not been countenanced in recent Admiralty boiler specifications for large vessels, which expressly stipulate that Yarrow or White-Forster boilers are to be adopted in certain cases, and Babcock boilers in others. This is the present position, and one which has obtained for a year or two, and indicates an important stage in the history of marine boilers. It is not clear why there should be two types of boiler adopted: still less is it certain that this will continue much longer. Why should the *Invincible* and *Inflexible* have Yarrow, and the *Indomitable* Babcock boilers? The coal results of the three ships for the same speed are almost identical; the Babcock boilers are slightly heavier, but have a somewhat better evaporative efficiency; the Yarrow boilers are simpler, but are possibly less easy to clean, though, on the other hand, they can stand

forcing much better—no mean advantage in case of necessity. The adoption of the two types in the same class of ship certainly indicates that while the Admiralty is convinced of the merits of the two types of boiler, neither is at present so overwhelmingly superior as to be adopted exclusively.

The Yarrow type—whether Yarrow or White-Forster in detail is immaterial, as we use the name more easily to distinguish the style of design as opposed to discarded types— is that inevitably adopted in all small craft. In the larger ships its presence is as frequent as that of the Babcock type, but in these vessels there is some doubt as to whether the most economical proportions of boiler have been achieved. The Navy adheres to 1¾-inch boiler tubes, and they do not facilitate good boiler design; it is still uncertain whether they are superior to 1½-inch tubes, which enable, in the opinion of many engineers, much more efficient dimensions to be achieved. In practically all the modern German ships, and in all sizes, only Schulz-Thornycroft boilers are used; the Babcock boiler is non-existent in the Navy. In France, on the other hand, the large-tube boiler with the relatively horizontal tubes is still generally adopted for all large warships, which are now still generally fitted with Belleville or Niclausse boilers. The United States Navy Department adheres steadfastly to the Babcock type, and has only tried the small-tube Thornycroft boiler for large ships in the *Maine* and *Missouri*. It is worth remarking that the individual size of boilers in many of the United States vessels is often considerably greater than in our own service. In France, for small craft the Normand boiler is general, though White-Forster boilers are being experimentally tried in two of the new destroyers. As recently as the *Achilles* and *Duke of Edinburgh* classes, the naval vessels were burdened with several cylindrical boilers in addition to their water-tube boiler. Since then, commencing with the more recent ships of the *King Edward* class, only water-tube boilers have been adopted, and these have given general satisfaction; boiler defects are now of very rare occurrence.

We need not now adduce figures of comparative weight and

space occupied in corroboration of the well known saving in these items by water-tube over Scotch boilers. What is of more peculiar importance at the present time is that great durability and freedom from breakdown have been shown by the performance of so many of our battleships and cruisers to accompany the use of boilers of this type. This being so, why are water-tube boilers not more generally adopted, especially in Channel steamers of high speed and small draught, in which the reduction of displacement due to their use would exercise a very important influence on the design? The reason lies to a large extent in the attitude of the registration societies, to whom the Yarrow type is relatively novel. Commercial questions of durability and efficiency are admittedly very important, but they do not stop at the stokehold. If the overall weight of machinery can be so reduced by the change as to counterbalance the repair bill to a large extent—whether by decreased size of ship or by greater cargo capacity made available—then the question of repairs is of less importance. The first step is to persuade registration societies to adopt less drastic—possibly unduly severe—regulations as to frequency of thorough overhaul. If we take the boiler-room weights of a big Channel steamer of the *Ben-my-Chree* type and of, say, about 14,000 indicated horsepower, we should have about 770 tons devoted to the cylindrical boiler equipment, and about 575 if Yarrow boilers were fitted. The difference in weight is 34 per cent. increase of cylindrical over water-tube boilers! Such a reduction is equivalent to a considerable saving—say 5 per cent.—on the whole ship, and is worthy of some effort on the part of shipbuilders and shipowners to acquire that detailed information as to the reliability of Admiralty boilers, which, for such purposes would, we feel sure, be generously afforded.

The general design of the triangular type of boiler has in Admiralty hands been considerably improved in late years. More space has been allotted for the better combustion of the fuel, the size of drums and water pockets has been increased, and the requirements as to either straight or White-Forster tubes being adopted has obviated nearly all of the trouble due

to the rapid wear of tubes, such as used to be experienced in the earlier types. As a further precaution, excessive combustion per square foot of heating surface has been curtailed to a limit of 1.1 pounds. This is far less than obtains in both the French and German Navies, where the torpedo-boat boilers are forced unmercifully. A generous allowance of grate area has also conduced to greater durability and efficiency, and in many other ways the boilers of today represent great improvements over those of eight or ten years ago. The attention that has of late years been devoted to types of engines, or to systems of heavy-gun armament, might find profitable matter in a reconsideration of the boiler question.—"The Engineer."

NAVAL BOILERS IN SERVICE.

By LIEUTENANT H. C. DINGER, U. S. N., in "International Marine Engineering."

In the fleet that encircled the globe there were the following types of boilers: Double-ended Scotch boilers (working pressure 180 pounds) in the *Kearsarge* and *Kentucky,* single-ended Scotch (working pressure 180 pounds) in the *Wisconsin, Alabama* and *Illinois,* Thornycroft boilers (working pressure 230 pounds) in the *Missouri* and *Ohio,* Niclausse boilers (working pressure 265 pounds) in the *Georgia, Virginia* and *Maine,* Babcock & Wilcox boilers (working pressure 265 pounds) in the *Nebraska, New Jersey, Rhode Island, Louisiana, Connecticut, Vermont, Kansas* and *Minnesota.* The cruise has been in a large measure a good test of the lasting qualities, reliability and adaptability of various types of boilers to conditions of extended cruising, and a review of the relative advantages developed, repairs now necessary and their general economy in coal consumption and repairs, is one of the valuable lessons that can be drawn from the steaming results and the general condition of boilers on their arrival on the Atlantic Coast.

Comparative Consumption of Coal.—Complete figures for

coal consumption for the run home are not at hand at present, but the total consumption of the vessels while running in company from San Francisco to Manila was published some time ago. The results are as follows: The average consumption of the *Connecticut, Louisiana, Kansas, Vermont, Minnesota, Nebraska, Rhode Island* and *New Jersey* was 5,481 tons. The trial displacement of these vessels is 15,625 tons. The average consumption of the *Georgia* and *Virginia* was 5,873 tons. The average trial displacement of these vessels is 15,000 tons. The average coal consumption of the *Ohio* and *Missouri* was 5,600 tons, the trial displacement being 12,500 tons. The average consumption of the *Kearsarge, Kentucky, Illinois,* and *Wisconsin* was 4,878 tons, the average trial displacement being 11,536 tons.

As the vessels differ in displacement, they should all be reduced to a common basis in proportion to the two-thirds power of their displacement. When this is done, the result is as follows:

	Tons.
Babcock & Wilcox vessels	5,481
Niclausse vessels	6,033
Thornycroft vessels	6,359
Scotch vessels	5,971

The saving of the Babcock & Wilcox boilers over the other types is thus: 552 tons over the Niclausse, 878 tons over the Thornycroft and 490 tons over the Scotch boilers. This is the result of only three months' service, steaming from San Francisco to Manila, via Australia. With this same proportionate saving carried on over several years it would soon cover the entire cost of boilers. This increase in economy, of course, means a corresponding increase in the steaming radius.

General Condition and Operation.—The Scotch boilers on the older vessels have been in constant service for eight or nine years, and are to a considerable extent worn out. These boilers now require a very considerable amount of repairs, and the question of reboilering these vessels with water-tube boilers

is now being considered. By reboilering with water-tube boilers considerable weight can be saved.

The Thornycroft boilers on the *Missouri* and *Ohio* have worked very successfully. They have been in service six and five years respectively, but now require retubing, and their brick work and casing also need considerable attention.

The Niclausse boilers on the *Maine* have never operated with any commendable degree of satisfaction, and the troubles, begun very early in the vessel's career, apparently have never been successfully overcome. This vessel has been very uneconomical, both as regards coal consumption as well as in engineering repairs. It may be fair to say that this condition is not entirely due to the boilers, but undoubtedly the boilers can well be charged up with a considerable share of the bad repute. The Niclausse boilers on the *Virginia* and *Georgia* are of a later type than those of the *Maine,* and have, during the three and two and one-half years of their service, given better satisfaction. The *Virginia* has, however, required a considerable amount of repair work to her casings, and the *Georgia* is also in need of considerable repairs to the brick setting of her boilers. The casings of Niclausse boilers in other vessels, such as the *Pennsylvania* and *Colorado,* have also given a great deal of trouble.

The Babcock & Wilcox boilers on the other eight vessels of the fleet have practically no repair work outside of the capacity of the ship's force; some of the boiler fittings, in common with those of the other vessels, require renewal and repairs.

Some of the principal causes for trouble are leaky bottom-blow valves. These valves have been the ordinary heavy bronze stop valves, and it has been difficult to keep these tight. A new valve of plug type, designed so as to prevent sediment cutting its seat, is being experimented with, and the use of valves with nickel seats and discs has also been suggested. In a number of cases some of the internal feed pipes have become detached, which defect is to be remedied by a new design of internal feed arrangement. Defective tubes have been discovered from time to time in all of the different types of

boilers. To guard against this it is necessary to have the very best material and to arrange the tubes so that corrosion and wear are reduced to a minimum.

The manner in which boilers are treated by the operating personnel and the hard or easy conditions under which they are caused to operate will, of course, have its full effect on the lasting condition of any boiler, and that boiler which can withstand most neglect and bad treatment without serious loss of efficiency has a most material advantage; for rough usage may of necessity be brought upon it on a naval vessel during war time.

Should defects in the tubes or pressure parts develop it is most important that they be easily remedied or repaired. The ability to make good a defective tube is, however, a point wherein the different types differ. In the Babcock & Wilcox boiler the ends of the defective tube may be plugged by simply lowering the water in the boiler, taking off the hand-hole plates at each end of the tube, inserting the plugs, refilling and starting up again. With the Niclausse boiler the defective tube can be withdrawn and a spare one inserted, which would require about the same time as to plug a tube in the Babcock & Wilcox boiler, but while it is comparatively easy to locate a leaky tube in the Babcock & Wilcox boiler, it is a much more difficult matter to locate a small leak on a Niclausse boiler. On the Thornycroft or others of the express type it is also much more difficult to locate a small leak, and to do so it is necessary to cool the steam and water drums so that a man may get into each, and when the tube is located the plugging must be done from the interior of these drums. In the case of the Niclausse or Babcock & Wilcox boiler the work of plugging or renewing of the tube is done by a man outside of the boiler. The Babcock & Wilcox boilers use an ordinary boiler tube which can be obtained at almost any large commercial center. The Niclausse boiler tubes are of special make, and for this reason cannot be as readily supplied in distant lands. To renew a tube in the Babcock & Wilcox boiler each tube can be taken out separately by itself, no others being

disturbed. In express boilers, except for a very few tubes, quite a number of good tubes may have to be cut out in order to get at the defective one. In some types of express boilers it is practically impossible to put in new tubes with the boilers in the vessel. In the express boilers, when a defective tube is discovered, it is usually plugged, and the process continued till there are so many plugged that the big job, often outside the capacity of the ship's force, of cutting out and replacing defective tubes is undertaken at a navy yard.

With the large-tube boiler, arranged for independent examination and withdrawal of tubes, a defective tube can be renewed at once. Usually you never stop to plug a tube, as a new one can be put in in very little extra time, so these boilers can be kept in constant repair by the ship's force. This is of immense military advantage, and though the arrangements necessary cost something and also add weight, they are well worth the price, because you can have a boiler always ready for service and not one with a large percentage of the tubes plugged off.

It is possible to go thoroughly all over a boiler of this type, replacing any part desired, while at the same time having the boiler ready for steaming in a few hours in case it is required.

Grease, Salt and Sediment in Tubes.—These are conditions which many will say should not exist, but the fact is they do exist, and while it is sometimes possible to keep all three—grease, salt and sediment—out of the boiler, conditions do and will continue to arise where you will have them. This being so, the proposition then is how can they be gotten rid of and how can their presence be told before their ravages have become extensive? It is most important to be able to know the exact condition of the heating surface so that precautionary measures may be taken. Of course, a great deal can usually be done by use of soda or other cleansers and frequent blowing, but for thorough cleaning the heating surfaces should be capable of being looked at and accessible to cleaning by direct mechanical means. In the Niclausse boilers the field tubes do not drain, so these methods are not very effective, and the

only effective way of getting the tubes clean is to remove the tubes and clean and replace them individually, a matter entailing a great deal of labor and also very careful work in replacement.

In the Babcock & Wilcox boilers each tube can be examined its full length and its surface thoroughly cleaned either with turbine cleaners, scrapers or brushes. In the express type of boiler this examination must be made from the interior of the drums, and if the tubes are bent the condition of their interior surfaces is never known. With the Babcock & Wilcox boiler any tube can be thoroughly examined inside of a few minutes. Thus any start at corrosion or wearing away can be detected and often remedied before it becomes a matter of importance.

Priming and Scale Formation.—One of the things that it is most desirable to avoid is priming. Some boilers guard against this by the use of steam drums. Small-tube or express boilers are peculiarly subject to priming when using salty or brackish water. Of course, boiler water is always kept as fresh as possible, but there are often unavoidable leaks in the condenser or other connections whereby salt water gets into the boiler. Sometimes there may not be time to repair the salt leak, and under these conditions a boiler that can be operated with salty water without priming has an advantage of considerable importance. One of the greatest drawbacks of the small-tube or express boilers is the excessive priming when water that is at all salty is used. The recent trouble with the boilers of the *Salem* at Charleston is an extreme example of this.

Large-tube boilers can be operated with salty water, and the Babcock & Wilcox boiler has repeatedly demonstrated its ability, on the around-the-world cruise, to operate without appreciable priming, even with a fairly high degree of saturation. Boilers employing the field tube do not operate successfully with salty water, and as sediment cannot be easily blown out, there is a much greater tendency to form scale. Thus the use of salt water in such boilers is attended with danger and difficulties.

In express boilers, when any scale has formed, there is much more danger of leaky or burnt-out tubes than in the Babcock & Wilcox or Scotch boilers, and when these troubles appear in small-tube boilers the tube ends are not as easily accessible, and renewals are difficult to accomplish. Where small tubes are used, especially if bent, there is considerable danger in the scale deposit forming to such an extent in certain places as to cause the tube to be partially or entirely plugged. If scale should form in a boiler with straight tubes and accessible ends the deposit can be thoroughly and easily cleaned out of the tubes, either by the use of scrapers or turbine cleaners. When scale or sediment of more than 1/16 inch thickness forms in small tubes (1½ inches diameter or less) it defies removal, either from straight or curved tubes, as no turbine cleaner of such small size can be made with parts sufficiently strong to stand up to the work.

Collection of Soot on Heating Surfaces.—In continuous steaming all boilers gradually collect a considerable quantity of soot on their heating surface. This collection reduces both the capacity and economy of the boiler to a very great extent, and hence a most vital point in the design of a successful boiler is the ease, feasibility and thoroughness with which this collection of soot may be removed while the boiler is steaming.

The ability to remove soot from the heating surface while steaming is one of the cardinal advantages of the Babcock & Wilcox boiler. By means of a steam or air lance, operated through the dusting doors provided in the sides of the casing, the soot is dislodged, and either carried up the smoke pipe by the draft or it drops down and lodges on the horizontal baffle laid over the row of 4-inch tubes immediately above the fire. By means of a door in the casing, this horizontal baffle can be thoroughly cleaned of the soot. So the boiler can be cleaned at any time and kept clean while steaming. In other types of boilers the means for cleaning tubes of soot while under steam are defective, and in no types yet put into use have the facilities for thoroughly cleaning the fire sides of soot ap-

proached in any respect those provided with the latest type of Babcock & Wilcox boiler. This advantage looms up particularly when steaming long distances at high power. Though many boilers show good results when starting out clean, as soon as the soot deposit becomes considerable the economy and free steaming of the boiler disappear or drop very materially.

Arrangements for Baffling Gases.—The economy of a boiler depends to a considerable extent upon the arrangements provided for baffling the gases of combustion and conducting them along the heating surface so that it will be most effective. The arrangement of the Babcock & Wilcox boilers allows for three passes across the nest of tubes. This brings about a rapid flow of gases past the heating surface at right angles to the length of the tubes and also keeps the gases in contact sufficiently long to enable practically all the available heat to be extracted, without a large ratio of heating to grate surface. The up-take temperature on Babcock & Wilcox boilers is remarkably low, and with good firing the temperature at the end of the last pass seldom exceeds 500 degrees Fahrenheit, even with as much as 2 inches air pressure.

The Niclausse boilers are not as well baffled. Their uptake temperatures are higher, and there is consequently a much greater loss of heat passing up the smoke pipe. Considerable difficulty is experienced in Niclausse boilers in securing baffling in place, and burning out the baffling tubes is a constant source of trouble.

Most types of express boilers are not well baffled to secure good economy and low up-take temperature. Owing to structural features in most types of express boilers satisfactory baffling cannot be fitted; frequent attempts at baffling these boilers have resulted in forming pockets from which it is practically impossible to remove soot and ashes.

Durability and Accessibility of Boiler Casing.—Another important feature from an operating point of view is the durability of the boiler casing and the ease with which damaged parts may be replaced. The sides and backs of the

Niclausse boilers are built up largely of brickwork, and in service this brickwork, due no doubt largely to the movement of the vessel, shock or firing guns, etc., cracks and deteriorates, so that considerable repairs are frequently necessary. Distortion of the casing, due to overheating, has also been experienced. The upkeep of the casings and brickwork of Niclausse boilers thus far used in service has been a matter of considerable expense.

Express boilers also require a considerable quantity of brickwork, which in many places requires frequent and continued renewal, also due to the positions of the lower drums; a considerable portion of the casing is in a position where conditions tend to corrosion and where examination and repairs are very difficult and in many cases impossible.

The durability and the ease with which any part of the casing of the Babcock & Wilcox boiler used in the United States Navy can be replaced by unskilled labor has been well demonstrated in the fact that there have been practically no repairs necessary to the casing of any of the later type of this boiler, though there are many hundred thousands of horsepower in service, and many have been in continuous service six years. With this boiler there are no easily damaged parts of the casing near the bilges, hence there is no corrosion to the casing. The casing is made in removable sections, and no part of the casing or boiler front supports any part of the pressure parts. The boiler can be completely stripped, with all the pressure parts and piping connections in place, and this can be done without cutting any rivets, and the casing can be replaced without the need of any new material except such as may have given away, but none of the parts have to be broken or damaged in any way in order to take the casing off. Furthermore, any defect in the casing can be easily seen, so that it can be made good before it is extensive. The accessibility of all parts of the boiler is such that any one can be removed with but very slight or no disturbance of any other part, and such removal can be accomplished by the ordinary fireroom force. Thus a side box, a mud drum or a header

can be taken out and replaced, the side box in a few hours, the header or mud drum in a couple of days, by the ship's own force and without any but ordinary boiler makers' tools.

The only seams on a Babcock & Wilcox boiler are on the steam drum; they have never been known to leak, and if by chance they should, the leak is readily seen and can easily be calked. In the case of express boilers, seams have often to be placed where it is difficult to calk them. Retubing or removal of a considerable number of tubes means an almost complete dismantling of the casing and usually the removal of many parts that are damaged in the process of removal.

Saving of Weight by Using Express Boilers.—The weight saved in express boilers has to be paid for, and it is paid for, as has been shown, in the excessive cost of repairs to these boilers and the difficulty encountered in renewals of various parts. (2) In the lack of economy in continuous, long steaming, due principally to lack of good baffling and the collection of soot, which cannot be effectively removed while the boiler is in use. (3) In the difficulties experienced when such boilers are called upon to use anything but thoroughly fresh and clean water, and the danger of leaks and tube failure where even slight deposits of salt are met with. (4) In the inability to make good slight defects as they are noticed, so that the boilers cannot be always in the best shape with the vessel in active service.

These conditions would bring out the question of whether the increased advantages in boilers of the Babcock & Wilcox type are really worth the increased weight and cost over express boilers. On a battleship the boiler weights are about 2½ per cent. of the total weight of the ship. By using some type of express boilers this weight might be reduced about three-fourths of 1 per cent. of the total weight of the vessel. On the score of weight saving it seems that this small extra weight, about 100 to 150 tons in our largest battleships, is well applied when the superior advantages are considered. As to first cost, some express boilers capable of doing the same work may be installed for about 20 per cent. less, but this difference

is easily made up in one or two years' repair bills, or a couple of years' increased economy of coal consumption, to say nothing of the increased military efficiency of being always ready for service.

The adoption of a light express boiler, or one of a less reliable, economical or durable type than the one which has thoroughly demonstrated its advantages would seem to be a decidedly backward step, and one that sacrifices military efficiency and preparedness to temporary expediency. It may be urged that foreign navies have, to a considerable extent, used express boilers on their battleships, and that, therefore, this move should be followed; but in answer to this it may be stated that the German Navy, or at least its battleships, do little extended cruising, and they never have had in their Navy a boiler that approaches the complete answer to practical naval requirements of that developed in our service, and though the British Navy does use large, straight-tube express boilers on some of its battleships, the larger portion of its recent installations consists of the English type of Babcock & Wilcox. Good express boilers have their field in torpedo craft and fast scout vessels, where economy, durability and reliability have to be sacrificed in order to get the weight for the necessary power. In large vessels of the fighting line, where the boiler weights are only about 2 per cent. of the total weight, this sacrifice is not necessary, and any step tending toward it would appear most unwise.

CRUISING TURBINES.

The decision of the Admiralty to forego the use of cruising turbines in the larger vessels of the recent program is the logical result of the numerous tests that have been made to determine their value. To the more progressive investigators the step will be very acceptable, for doubts have long been felt in many quarters as to their value. In the destroyers they are to be retained for the present; vessels of this type utilize a far greater range of power than the larger ships, and the cruising

turbines have a better chance of justifying their existence; but even in this class their retention is problematical. Wider experience in the design of marine turbines has enabled a much closer harmonization of blading proportions and propeller dimensions to be achieved, with a corresponding increase in efficiency, so that the proportionate utility of the greatly increased number of rows of blades introduced by the auxiliary turbines is largely discounted. In the early days when the marine turbine was struggling to effect its entrance in warship design, criticism was invariably, and often very inaccurately, directed at the greatly increased consumption at low powers. This, it was explained, was due to the relationship of steam speed and blade velocity falling off as revolutions were reduced. The steam speed could be brought down proportionately by inserting auxiliary turbines, and this was done, the increase of weight and complication being apparently accepted without demur. Certainly, in many cases the use of cruising turbines reduced the consumption at low powers; but it is very probable that with the addition of far less weight to the main turbines the same results could have been obtained at low powers and considerably better results at full power. Experiments that have been made in the last two years show that under many circumstances cruising turbines are disadvantageous. When out of work they must be kept connected to the condenser in order to reduce the drag on the shaft; even then they exert a retarding effect, while if any air enters additional work is not only needed to drive them, but is also thrown on the air pumps. When working at very low powers, instead of the main low-pressure turbines, to which shaft they are invariably coupled, having to drive the cruising turbines, the cruising turbines are obliged to drive the main turbines. The inlet pressure of the steam is very low at the low powers, and the expansion is completed long before the main exhaust pipe is reached, so that there is no more energy available for doing work in the last few stages of blades. Measurements of temperature show that the steam is often superheated at the exhaust pipe under these conditions; that is to say, that the

last rows of blades have been doing work on the steam and not receiving power from it, so that this is negative work done by the cruising turbine on the same shaft. Another curious feature about cruising turbines is the prevalence of blade stripping in them compared with the main turbines. Nearly all the accidents due to this that have happened in the Royal Navy have been in the cruising turbines. Partly it is due to the collection of water while the turbine is running idle, sometimes due to the cylinders distorting when hurriedly put under steam, and perhaps also to the " jumping " of the spindles when suddenly the astern power is applied.

The principle of carrying dead weight which is only useful to a limited extent under special conditions could not be continually upheld. In the *Dreadnought* class the cruising turbines weigh between 80 and 90 tons, besides occupying nearly as much space as the two high-pressure cylinders themselves. The ship uses about 18 tons of coal an hour at full power, so that to substitute coal for cruising turbines adds between four and five hours steaming—a hundred knots—on to the full-power radius of action. In the ocean-going destroyers the cruising turbines weigh about 20 tons, equivalent in oil fuel to two hours at full power, or 13½ per cent. of the total capacity. The cruising turbines do not save that much at 15 knots compared with the main turbines only, and as the full-power radius is so greatly increased their retention can hardly be justified. Moreover, as the complication involved is considerable, and as the essential valves and pipes occupy in many cases unavoidably inconvenient positions in the engine room, the decision of the Admiralty will meet with hearty approval from the sea-going staff.

With the Parsons type of turbine it is, of course, impossible to allow the annular area between cylinder and rotor that is available for the flow of steam, but with the nozzle type of turbine, in which the steam passages are of greatly reduced area, this can easily be done at the high-pressure end, so that an area more in proportion to the steam volume can be arranged. This is the system adopted in the Japanese battleship

fitted with Curtis turbines, and in the United States cruiser *Salem,* and, in a modified form, is the basis of governing adopted for Curtis turbines for electric generating purposes. In these the economy obtainable over a very wide range of power is remarkable, and it is largely due to the accurate proportion of steam-passage area to volume. The use of auxiliary turbines was a more cumbrous method of attaining the same result, and the reported decision of the Admiralty to fit impulse turbines of the Curtis type in the new cruiser *Bristol,* is a natural corollary to the decision to give up cruising turbines.—" The Engineer."

THE LOW-PRESSURE TURBINE IN MARINE SERVICE.

A few issues back a short note was published on the trial trip of the *Laurentic,* and information more in detail is now available from " Engineering." The *Laurentic* was designed for the Canadian trade to run between Liverpool and Montreal and made her first trip during the latter part of April. She is the first Atlantic liner to be fitted with a combination of reciprocating and turbine machinery and is also notable from the fact that she inaugurates the White Star service to Canada, besides being larger than any other ship in the Canadian service. Her length is 565 feet 6 inches over all; beam, 67 feet 3 inches, and depth, molded, 45 feet 6 inches. The registered tonnage is about 15,000 tons and the displacement at service draught about 20,000 tons. The ship has a passenger-carrying capacity of 260 first class, 430 second class and 1,000 third class.

A sister ship, the *Megantic,* differing only in the machinery installed, has also been built for the same service. The latter vessel left Liverpool on her maiden trip to Montreal on June 17, and there will soon be available accurate comparative data of the performances of the two different types of machinery, the *Megantic* being equipped with reciprocating engines only. The data will be all the more interesting as the results obtained will be utilized in selecting and proportioning the machinery

of the two immense White Star liners, *Olympic* and *Titanic*, now being built at Belfast. These vessels will be put in commission about 1911 and will register about 45,000 gross tons, with machinery of nearly 50,000 horsepower capacity to give a speed of 21 knots.

In both the *Megantic* and *Laurentic* six double-ended steam generators have been installed for a working pressure of 215 pounds. The allowance in heating surface is in accordance with the usual White Star practice, about 2½ square feet per horsepower, while the ratio of heating surface to grate area is 37 or 38 to 1. In the *Laurentic* the two reciprocating engines are of the triple-expansion type with four cylinders, 30 × 46 × 53 × 53 × 54-inch stroke, to insure perfect balance. The general design follows Harland & Wolff's practice, with single columns, which gives an open engine.

The low-pressure turbine of Parsons' latest type is in the center of the ship and abaft the main engines, with one condenser on each side, while the auxiliary machinery is arranged in the wings. The exhaust pipes from the two low-pressure cylinders, which are at the extreme ends of each engine, are led with the usual expansion, or bellow, joint to the forward end of the turbine. On each pipe there is a double-beat valve, operated each by a separate high-pressure engine secured to the after bulkhead in the engine room, and controlled by levers at the reciprocating-engine starting platforms. These engines and valves can be worked independently, but are normally connected and worked simultaneously.

For all maneuvering the turbine will be thrown out of action, that is, when the telegraph indicates "stand by" the double-beat valve will pass steam to the condenser and the ship will maneuver as a twin-screw steamer. The benefit in having an independent valve is that should one of the engines break down two propellers will be available for driving the ship, one rotated by the reciprocating engine in service and the other by the turbines. There is thus the advantage that with one engine out of use two-thirds of the total power would be available instead of one-half, as in an ordinary twin-screw

ship, so that the reduction in speed would be considerably less. The trial-trip results showed the possibility of this maintenance of high power with one engine out of service, as the low-pressure turbine developed 4,600 horsepower out of a total of 12,400 horsepower. The exhaust pressure from the reciprocating engine, and therefore the initial pressure in the turbine, was about 18 pounds absolute. The speed obtained exceeded the 16 knots anticipated by the design, and the main engines operated at 83 revolutions per minute, while the turbine made 220 revolutions.

The turbine gives 28 shaft horsepower per ton. The thrust bearing is at the forward end, with the forward main bearings between this thrust and the rotor, and the after bearing abaft the rotor. The blading is arranged for six expansions, the lengths being from 6 inches to about 10 inches, while the average clearance is about ⅛ inch. There is the usual arrangement for adjustments, and the bearings are lubricated by gravity, with two standby oil pumps. The shaft bearings are also water cooled, and, in order to obviate any matter passing over with the steam to the turbines, strainers have been fitted in the steam pipes.

In the *Megantic,* which is twin-screw, the engines are of the quadruple-expansion type, the cylinders being 29 × 41½ × 61 × 87 × 60-inch stroke, which proportions give a very satisfactory range of expansion. The condensers form part of the framing, and the air and circulating pumps are placed contiguous to the condenser. The auxiliary machinery in both ships is of the most comprehensive type.

While it is too early to speak with confidence as to the measure of economy obtainable under service conditions in the *Laurentic,* the full-power trials, although of short duration, gave highly efficient results. The water consumption for the main engines was appreciably under 13 pounds per horsepower per hour, as compared to 16 pounds required by the average Atlantic liner with triple-expansion engines. The rate of evaporation in the boilers was eight pounds per pound of Welch coal and slightly less with Yorkshire coal. It must be

considered, however, that the weight of engines and space occupied are greater when the turbine supplements the reciprocating engine, but the reduction in steam consumption justifies less boiler power and less coal in the bunkers, so that on a balance the weight may be about the same. The system is especially applicable to vessels of less than 18 knots speed, in which neither weight nor space is of such importance as in high-speed ships. Primarily the question of engine-turbine combination is one of economy, and the comparative data obtained from the two sister ships should prove of exceptional interest.—" Power and The Engineer."

THE TOTAL HEAT OF SATURATED STEAM.*

For many years Regnault's classic formula, now sixty-one years old, which gives as the total heat of saturated steam

$$H = 1091.7 + 0.305\ (t - 32)\ \text{B. T. U.},$$

has been exclusively used by engineers in America, yet the remark is becoming common that such and such a method cannot be used because of the well-known errors in the steam table. It is therefore fortunate that, at least in the range from 32 to 212 degrees, physicists have recently provided a considerable number of good observations of the total heat of saturated steam apparently not noticed by the makers of our steam tables. It is equally unfortunate that in all these years there seems to have been not a single new observation above the boiling point. It is the purpose of this paper to show that certain observations recently made for very different purposes can be combined to give a better set of values of H above 212 degrees than do Regnault's direct measurements, and to propose a new formula for the range from 212 to 400 degrees, the accuracy of which is believed to be something like 0.1 per cent. If these results are correct, Regnault's formula is too high by more than 18 B. T. U., or 1.7 per cent. at 32 degrees; too low by 6 B. T. U., or 0.5 per cent. at 275

* By Dr. Harvey N. Davis, abstracted from a paper presented at the December, 1908, meeting of the American Society of Mechanical Engineers, New York.

degrees, and too high again above 380 degrees, the error increasing rapidly at high temperatures.

Some years ago attempts were made to determine the variation of the specific heat of superheated steam with pressure and temperature by means of throttling or wire-drawing experiments. These attempts failed because, as the observers themselves pointed out, the necessary computations were extremely sensitive to small errors in the assumed values of the total heat of saturated steam. Under unfavorable circumstances an error of 0.1 per cent. in one of the values in the steam tables might make a difference of from 3 to 5 per cent. in C_p. It is then evident that, knowing C_p independently, one could reverse the process by which they tried to get it, and compute all the total heats in terms of any one by a method as insensitive to errors in assumed data as the other was sensitive.

Fortunately, since these experiments C_p has been determined independently and directly by Knoblauch and Jakob, of Munich, and by Thomas, of Cornell, and the accuracy attained by them is sufficient to make worth while such a recomputation of the wire-drawing experiments. In this work Knoblauch's values of C_p will be used rather than Thomas'.

The throttling experiments used are those of Grindley, in England, in 1900; of Griessmann, in Germany, in 1904, and of Peake, in England, in 1905. The recomputation of these throttling experiments, considered in connection with Knoblauch's determination of the specific heat of superheated steam, lead to a new formula for the total heat of saturated steam, namely:

$$H = H_{212} + 0.3745\ (t - 212) - 0.000550\ (t - 212)^2.$$

The best available value of H_{212} seems to be 1150.3 mean B. T. U., which is the average of the values of Henning and of Joly. The total heat equation becomes

$$H = 1150.3 + 0.3745\ (t - 212) - 0.000550\ (t - 212)^2.$$

The range of this formula is from 212 to about 400 degrees Fahrenheit. The greatest errror in Regnault's formula in this range is 6 B. T. U., at 275 degrees Fahrenheit; but if Reg-

nault's formula is extrapolated to higher temperatures, the error in it increases very rapidly. Below 212 degrees there is an abundance of modern data to show that Regnault's formula runs high, the error reaching 18 B. T. U. at 32 degrees.

Recomputed values of the specific volume of saturated steam differ from the standard values by 101 cubic feet, or 3 per cent. at 32 degrees, and by about 1 per cent. in the opposite direction at 275 degrees. Computed values of C_v at saturation agree strikingly with Knoblauch's values, and give additional confirmation to a conclusion already reached that of the three available sets of C_v values, Knoblauch's, Thomas' and Heck's, Knoblauch's is most deserving of confidence.

A steam table based on these new values will presently be published under the joint authorship of Prof. Lionel S. Marks and the present writer.—" International Marine Engineering."

TESTS OF HIGH-DUTY PUMPING ENGINES WITH AND WITHOUT SUPERHEATED STEAM.

Some recent official tests of four 30,000,000-gallon pumping engines for the city of Cincinnati were described in a paper by Mr. John Primrose. These tests show that even when a modern high-duty pumping engine, which has reached a stage of development where it is conceded to be the most economical of all reciprocating engines, is performing at its highest point of efficiency, there is a very satisfactory increase in economy by the use of a moderate superheat.

The station contains four three-cylinder, triple-expansion, vertical pumping engines of the crank-and-flywheel type, each having a capacity of 30,000,000 gallons in 24 hours. The diameters of the steam cylinders are 29, 54 and 82 inches, and of the plungers, of which there were three, 37½ inches. The stroke of all pistons and plungers is 96 inches. All cylinders are steam jacketed on their barrels, and reheaters are provided between the cylinders. Each engine is provided with its

own surface condenser. The boilers are of the Stirling type, and have 2,016 square feet of heating surface each. They are equipped with American stokers, having 42 square feet of grate surface. There are two direct-fired Foster superheaters, each containing 1,160 square feet of heating surface and 8 square feet of grate area, and several Green economizers. The steam line was rather long and of larger diameter than necessary, causing a loss of superheat of about 20 per cent. Pittsburg nut and slack coal was used in tests.

The records of official tests show that there is a considerable reduction in the steam used in jackets and receivers, which indicates that cylinder condensation is less with superheated steam. It is further interesting to note that the temperature of the exhaust steam leaving the low-pressure cylinder is much less when using superheated steam, which is undoubtedly due to less heat being absorbed by the steam from the cylinder walls during the exhaust stroke in the low-pressure cylinders. Another advantage of using superheated steam is found in reducing the leakage of valves and pistons.

The duty was found to be 194,403,500 foot-pounds per 1,000 pounds of dry steam, with 95 degrees superheat at the throttle; 189,624,000 foot-pounds, with 99 degrees superheat, and 169,250,000 and 171,700,000 foot-pounds without superheating.

During the tests the superheater was operated at only about one-third of its capacity, and it is only fair to assume that the superheater would give better efficiency when operating more nearly at its full capacity. The amount of steam used by the auxiliaries is comparatively small, but the benefit of using superheat on these auxiliaries is very marked, and this has resulted in the superheat increasing the thermal efficiency of the plant more than the thermal efficiency of the engine considered by itself.

The steam and coal consumption of these engines when using saturated steam is so good that it is remarkable. Still there are losses which to a certain extent can be decreased by using superheated steam.—"The Engineering Record."

ENGLISH NAVAL NOTES.

The Neptune.—The new first-class battleship *Neptune* was officially commenced at Portsmouth on the 19th ult., and as much material has been collected in readiness, her construction should now proceed rapidly. The new ship will be an improvement not only on the *Dreadnought,* but also on the *St. Vincent* class. Her dimensions are, it is stated, to be as follows: Length, 510 feet; beam, 86 feet; displacement, 20,000 tons (about), and her speed is to be 21 knots. Her armament will be the same as earlier vessels of the type, viz: ten 12-inch guns, mounted in pairs in barbettes—one forward, two astern, and one on either bow. The inner after turret is to be raised so that the guns will fire over the top of the extreme stern turret, which will give an additional stern fire of two guns more than the earlier vessels of the class. The anti-torpedo armament will consist of a new type of 4.7-inch guns.

It has been announced by the White Star Line that, owing to the great success achieved in the recent trials of the *Laurentic,* which is propelled by a combination system of reciprocating and turbine engines, they have decided to adopt the same mode of propulsion in their two giant liners, *Olympic* and *Titanic,* of 45,000 tons each, now building at Belfast. In the *Laurentic's* trials, the pressure at the engine stop valve was 240 pounds per square inch, exhausting to 70 pounds per square inch into the turbine engines.

The torpedo-boat destroyer Tartar, which eclipsed all speed records on her original trials by steaming for six hours at a mean speed of 35.5 knots, has outstripped all previous performances by steaming for nearly an hour at the rate of over 40 knots. The recorded speed for the best mile was 40.3 knots, equivalent to almost forty-six miles an hour. The *Tartar* and her sister ships are fitted for burning oil fuel exclusively. With engines of 14,500 horsepower she requires only seventeen stokers; the scouts of the *Attentive* class, with only 1,000 more horsepower, require 107 stokers, their furnaces being fitted for burning coal. She burns Texas oil fuel.

It is stated that the protected cruiser about to be built for the Royal Navy by Messrs. John Brown & Co., Ltd., of Clydebank, is to be fitted with the Curtis steam turbine, the exclusive right to manufacture which in this country has been acquired by them. Both in the United States and Germany this turbine has been installed in vessels with satisfactory results, but it has not been tried here until now. The action of the Admiralty in fitting this turbine to ships of practically identical design hitherto fitted with the Parsons turbine, will give the engineering world a chance to make comparisons between the American and British turbines, and the results of the trials will be watched with considerable interest.

In a recent homeward passage the Cunard liner *Mauretania* broke all previous records by maintaining an average speed of 25.20 knots across the Atlantic Ocean, thereby earning for herself the distinction of being the fastest ocean liner afloat. Her best average speed for one day was 26.17 knots, but her most remarkable performance was in the Channel, when she maintained the speed of 27.4 knots for four hours. During her recent overhaul, alterations were made in her propeller arrangements, four-bladed propellers of a solid type being fitted to the wing shafts in place of propellers having three blades. The new propellers fitted on the wing shafts weigh 18 tons each, while the three-bladed propellers on the center shafts weigh 22 tons each. Under ordinary weather conditions, the *Mauretania* should have very little difficulty in maintaining her contract speed of 24.5 knots, whilst under ideal conditions her recent record may yet be eclipsed.

Statement Explanatory of the Navy Estimates, 1909-1910.—The Estimates for 1909-1910 amount to £35,142,700, as compared with £32,319,500 for the current year.

Shipbuilding and Repairs.—New construction for the year will cost £8,885,194, as against £7,545,202 for 1908-09. £6,599,424 will be spent on a continuation of work on ships already under construction, and £2,285,770 for beginning work on ships of the new program, for which financial provision is

made in the Estimates as follows: Four battleships (*Dreadnought* type), six protected cruisers, twenty destroyers, and a number of submarine boats, for which a sum of half-a-million pounds is allowed.

In addition to the above provision for ship construction His Majesty's Government may, in the course of the financial year 1909-10, find it necessary to make preparation for the rapid construction of four more large armored ships, beginning on the 1st April of the following financial year. They therefore ask Parliament to entrust them with powers to do this effectively; such powers would enable them to arrange in the financial year 1909-10 for the ordering, collection and supply of guns, gun mountings, armor, machinery and materials for shipbuilding, thus making possible the laying down on the 1st April, 1910, of four more ships, to be completed by March, 1912.

The estimated time for the completion of a battleship is now taken as two years; but this period does not cover the whole time during which work is being done in obtaining necessary materials and in the manufacture of certain parts of the ship's equipment, such as gun mountings. Three months' notice in advance ought to be given to contractors to ensure completion within two years from the date of the order of the hull, and if an exceptionally heavy demand were to be made on the contractors, much longer notice would be required. The actual date of "laying down" can indeed be postponed for some time without delaying the final completion of the ship, provided that work is proceeding in the manufacture of guns, gun mountings, machinery and armor, and that the materials for the hull are all collected at the yard ready for immediate building. It is on an estimate of time in which allowance is made for these facts that the period of construction of a battleship is reckoned at two years.

For some years past it has been the practice for ships of the new program to be laid down very late in the financial year. An obvious effect of this system is to postpone for some two years a large part of the financial burdens of the program

to which the ships belong. In the program of the new financial year two battleships are to be laid down in July, which is the earliest date on which we can lay them down, having regard to the necessary notices to contractors for the supply of certain parts of the ship. Two more battleships are to be laid down in November, and in respect of these four ships a sum of £1,531,600 is taken in the Estimates.

There will thus be heavy payments required for four new battleships during the first financial year of their construction, the excess on this item over the corresponding charge of last year being £1,274,215.

£150,000 of the increase under section II of Vote VIII is caused (as in Votes II and IX) by the necessity for cash provision of stores, which have in previous years been taken out of stocks without replacement.

The great fall in the price of coal, and the state of the shipbuilding trade, has enabled the Admiralty to place orders for the annual requirements of coal for the fleet and for the new ships of the current year's program on most advantageous terms.

Between the 1st April, 1908, and the 31st March, 1909, the following ships will have been completed and become available for service:

3 Battleships (*Lord Nelson* (delayed from previous year,) *Agamemnon* and *Bellerophon*).
4 Armored cruisers (*Indomitable, Inflexible, Invincible,* and *Defence*).
5 Destroyers—Tribal class (three delayed from last year).
17 First-class torpedo boats (coastal destroyer type).
7 Submarines.

On the 1st April, 1909, there will be under construction:

6 Battleships.
1 Armored cruiser (*Invincible* type).
2 Unarmored cruisers.
5 Second-class protected cruisers.
25 Torpedo-boat destroyers.
6 First-class torpedo boats (coastal destroyer type).
19 Submarines.

I am glad to be able to say that cooling machinery for the cordite magazines on board H. M. ships has now been provided for all completed battleships and cruisers which are likely to be retained on the active list, and for all ships under construction except destroyers and smaller craft.

The long continuance of the labor disputes in the private shipbuilding yards has seriously delayed the progress of most of the ships that were under construction during the year.

The Board are giving careful attention to the possibility of constructing floating docks for the repair of men-of-war of various sizes. The idea, of course, is no new one, but the serious want of dock accommodation for our biggest ships on the east coast, and the long time that the construction of permanent works on shore is bound to take, justify an exhaustive investigation of the question, whether the provision of floating docks at certain of our ports would not be an advisable step. Floating docks possess the great advantage of mobility, and for torpedo craft they could probably be used with safety at several ports where they are much needed. There are, however, unquestionably great difficulties in the use of floating docks for the repair of big ships. On the English coasts the large rise and fall of tide makes the safe moorings of floating docks in close proximity to a dockyard or a shipbuilding center a very serious problem, and the depth of water needed is so great that a considerable amount of dredging would be necessary in many localities.

The question of the use of dirigible airships for naval purposes has been under consideration, and it has been decided to carry out experiments and construct an aerial vessel.

Personnel.—A full report has recently been presented to the Admiralty from the flag officers who have been in charge of the vessels manned by nucleus crews on the system, which has now been at work for some four years. The reports received are of a most favorable character, and all the flag officers concerned agree that the nucleus-crew system ensures a readiness for war and a general efficiency which has never before been obtained—at least since the introduction of steam machinery

into the Navy. It must be remembered that before the introduction of the nucleus-crew system such ships as were not fully manned were entirely without officers or crew, and left laid up in the dockyards, which they never left until their turn came for full commission. Now, on the other hand, the ships are taken to sea for cruising and gunnery practice, and are thus kept in a state of working efficiency that could not otherwise be contemplated. The chief advantage, however, obtained under the system of nucleus crews is the greatly increased proficiency in gunnery due to the more permanent association of the principal officers and men with the ship and her armament. The recent battle practice returns are a most satisfactory evidence of this.

While practically all ranks and ratings in the fleet have received increases of pay from time to time during recent years, officers of the rank of commander have been still paid the same rate as they were in 1864. It has accordingly been decided to increase the full pay of commanders from 20s. to 22s. a day. It has afforded the Board of Admiralty very great satisfaction to have been able thus to show their appreciation of the value of a class of officers on whose loyal and praiseworthy exertions so much of the efficiency of the fleet depends.

During the past year it was decided to introduce, experimentally, in the general depots at the home ports, a system of payment in advance to men going on long leave of a proportion of the pay which would become due to them while absent, as had previously been done in the case of marines serving at headquarters. The experiment has proved thoroughly successful, the concession being very satisfactory to the men without involving expense to the Crown, and it is now proposed to extend it to all ships and establishments at home.

Until lately it was the practice to withhold a portion of the wages of men who made allotments from their pay to relations at home, in order to safeguard the Crown against loss in case of desertion. Last year it was decided to abolish this allotment reserve, and the result has evidently been much appreciated by the men, as the number of allotments made during the

past year has increased by upwards of 5,000, and there has been a material reduction in the number of applications made to the Admiralty for support by relatives of men in the naval service.

Works.—The contract for the graving dock, closed basin and entrance lock, to be constructed at the new naval base at Rosyth, has recently been placed with an eminent firm of engineers, who are required to complete the work in seven years, and will be given a substantial bonus for each week that they can save on this time. The same inducement for early completion has been offered to the contractors for the new lock at Portsmouth which was ordered last August and is a matter of pressing necessity owing to the increased size of modern armored ships.

A large increase of magazine accommodation has for some time been urgently required, and after careful examination of various sites in the United Kingdom for the establishment of a magazine depot, some property has been secured a few miles above Rosyth on the north shore of the Firth of Forth, and plans for its erection are being designed.—"J. R. N. S. I."

FRENCH NAVAL NOTES.

Précis of M. Chaumet's Report on the Estimates: Present State of the French Navy.—M. Chaumet states that the age of battleships has been fixed to count from the date of their launch. He draws attention to the slowness of the rate of construction, pointing out that the last unit of the battleships of the 1900 Program was only completed ready for commissioning in August, 1908. These battleships were of a superior type to their foreign rivals when they were designed, but by the time they were completed they were relatively obsolete, and the same applies to the armored cruisers.

"Our torpedo boats," he complains, "are of less tonnage than those of foreign navies, while the displacement of these latter has steadily increased, that of French boats has decreased. The last group constructed, vessels of 98 tons, are of very

doubtful value. They are not fit to keep the sea when the weather is at all rough, and they have so little stability that it has been necessary to give them 3 tons of ballast. The necessary repairs also immobilize a large number of the boats, nearly 50 per cent. awaiting repair in the different ports.

"The greater part of the submarines and sumersibles—those of small tonnage like the *Naïade, Phoque* and *Dorade* types, with their limited sphere of action—can only await the enemy in the vicinity of their stations. It is only the submersibles and submarines of recent construction with a greater displacement that are capable of taking the offensive.

"Thus our first line does not really come up to the numbers given in our second table (page 389, March "Journal").

"This is not all. The question next arises as to what extent we can depend upon our battleship squadrons, and the answer is not encouraging.

"A squadron is not only the sum of the units which compose it: it must be organized, coherent and provided with all necessary auxiliaries.

"Even if we only had—which we have not—battleships which are homogeneous, it would not suffice merely to group them to have a squadron ready for battle.

"As an army is not constituted exclusively of infantry, so a fleet requires scouts, repeating ships, destroyers, properly-equipped mine vessels and factory ships, which can carry out urgent repairs."

M. Chaumet then proceeds to point out that the battle fleet is unprovided with any of these special adjuncts, although it is asserted in some quarters that there is no need for special scouting vessels, as this duty can be carried out by the armored or protected cruisers, or even by fast mail steamers transformed into auxiliary cruisers or by destroyers. He does not, however, consider it prudent that the armored cruisers should be employed in scouting work, as they might be drawn into such a position by the enemy that, without the speed to avoid an action, they would yet be too weak to accept with chance of success. The protected cruisers are almost as inoffensive as

mail steamers, and without the necessary speed. Auxiliary cruisers, provided they have the necessary speed, should be requisitioned from the mercantile marine and made as much use of as possible in time of war.

It would be wise, in M. Chaumet's opinion, to comply with the demand made by Vice Admiral Germinet, when in command of the Mediterranean Fleet, and build at least four scouts for service with that squadron. These ships should not cost very much, as they would only be of sufficient tonnage to be able to keep the sea in all weathers, while for armament it would only be necessary to give them guns to protect themselves against the attacks of destroyers, and in this connection M. Chaumet recalls the evidence given by Vice Admiral Pottier, at that time Commander-in-Chief in the Mediterranean, before the Commission of Enquiry, in 1894, who stated that "if he had his way, he would not arm vessels of this class, so that they should not be tempted to fight. The sole duty of a scout should be to discover the enemy and then report the fact immediately. If the enemy fired at her and she carried guns, she might be tempted to reply, and thus not carry out her first duty." Destroyers could not act efficiently as scouts; their radius of action is too limited, and their displacement too small to allow of their maintaining in bad weather their nominal speed, and they would soon be at the mercy of the enemy. Moreover, there are not enough of them for any to be spared for scouting duty, as a squadron of twelve battleships and six cruisers would alone require at least twenty-four for its efficient protection.

M. Chaumet considers that repeating ships can be found, if necessary, among the small cruisers; while it is also necessary that some of them should be fitted out as mine ships, bearing in mind the important part floating mines played in the Russo-Japanese war. In view of the dangerous nature of this mine work, it is necessary that the men who would have to handle them in time of war should be thoroughly trained in peace. Another serious defect in the ships of the fleet, to which attention is drawn, is that only one range finder is supplied to each

battleship and cruiser, and this is placed in an exposed position, unprotected in any way, so that it might quite possibly be destroyed by the first shot fired. It is advisable, in his opinion, that at least two should be supplied, and that they should be placed in the conning towers.

M. Chaumet next points out that battleships, destroyers, or even submarines, do not by themselves constitute a war fleet. There must be proper reserves of guns, projectiles, torpedoes, ammunition, coal and stores of all kinds, and, above all, there must be a sufficiency of docks and repairing basins, and unless all these conditions are fulfilled "we have a fleet only outwardly in appearance, but not one ready for war."

Coming to the question of the personnel, the only battle squadron is that in the Mediterranean, which is composed of two active and two reserve divisions. The two active divisions ought to be in full commission with their crews complete, but nevertheless they are, on an average, 500 men short of their complement. Similarly the two reserve divisions have only just sufficient men on board to keep them clean, but not enough to take them to sea. The result is, that in case of mobilization there are three courses open, each of which is fraught with danger: 1. Either to wait until the men to complete the effectives arrive from Brest, Lorient or Toulon, as the case may be; 2. Or the two active divisions must leave without the two reserve ones; 3. Or the whole four divisions will have to leave with their effectives incomplete.

There can be no question that the battle squadron should always have its effectives complete, so as to be ready to weigh at once at the first signal. In order to bring the reduced crews of the third and fourth divisions up to full strength, 885 petty officers and men will be required, and if to these the 500 men short in the two active divisions are added, some 1,300 men in all must be drawn from somewhere before the fleet can put to sea fully manned. In addition, there are continual complaints from the torpedo flotillas, the engines and boilers of which require constant and careful attending to, of the shortage of engine-room mechanics and stokers.

The constant changes in the personnel of the ships, both among officers and men, is also to be deplored, 50 per cent. being disembarked annually; the result being that, although the period of service on board is fixed by the regulations at three years, the warrant officers, petty officers and men remain, as a rule, less than two years on board. Some of these changes are, of course, unavoidable, but in the Mediterranean Fleet alone over a thousand men are disembarked every year, and it ought surely to be possible to regulate things better than this.—*Rapport par M. Charles Chaumet* (*Budget Général de l'Exercise, 1909, Ministère de la Marine.*)

GENERAL NAVAL NOTES.

The warships, exclusive of torpedo boats and submarines, launched during the year 1908, with their tonnage, I.H.P., and estimated speed, were as follows:

Great Britain.—First-class battleships: *St. Vincent, Collingwood,* both of 19,250 tons, 24,500 I.H.P., and 21 knots speed. Third-class cruiser: *Boadicea,* 3,400 tons, 18,000 I.H.P., and 25 knots speed. Destroyers: *Amazon, Saracen,* 880 tons, 15,500 I.H.P., and 33 knots speed.

Austria-Hungary.—First-class battleships: *Erzherzog Franz Ferdinand,* 14,600 tons, 20,000 I.H.P., and 20 knots speed.

Brazil.—First-class battleship: *Minas Gereas,* 20,000 tons, 25,500 I.H.P., and 21 knots speed.

Denmark.—Coast-defence battleship: *Peder Skram,* 3,680 tons, 4,600 I.H.P., and 15.5 knots.

France.—First-class armored cruiser: *Waldeck-Rousseau,* 14,000 tons, 36,000 I.H.P., and 23 knots speed. Destroyers: *Glaive, Poignard, Chasseur, Hussard, Voltigeur, Spahi,* 450 tons, 6,800 I.H.P., and 28 knots speed.

Germany.—First-class battleships: *Nassau, Westphalen, Rheinland, Posen,* 18,000 tons, I.H.P. and speed not published. First-class armored cruiser: *Blücher,* 15,000 tons, I.H.P. and speed not published. Third-class cruisers: *Emden, Kolberg,*

4,300 tons, 20,000 I.H.P., and 25 knots speed. Destroyers: twelve, six of 680 tons, six of 616 tons, 10,250 I.H.P., and 30 knots speed.

Italy.—First-class cruisers: *San Giorgio, Amalfi,* 9,800 tons, 19,000 I.H.P., and 22.5 knots speed. Destroyers: *Calypso, Climene,* 375 tons, 6,000 I.H.P., and 29 knots speed.

Japan.—Third-class cruiser: *Moyami,* 1,350 tons, 8,000 I.H.P., and 23 knots speed. Destroyers: 32 under construction, but number launched during 1908 not known.

United States.—First-class battleships: *South Carolina, Michigan,* 17,900 tons, 16,500 I.H.P., and 18.5 knots speed; *North Dakota,* 20,000 tons, 25,000 I.H.P., and 21 knots speed.

The total tonnage of the warships, including torpedo vessels and submarines, launched for each country during 1908 is as follows: Germany, 97,660 tons; United States, 52,850 tons; Great Britain, 49,560 tons; Italy, 29,400 tons, France, 21,600 tons; Russia, 8,800 tons; Japan, 2,245 tons; other Powers, 47,574 tons; making a total of 127 ships, with a displacement altogether of 309,689 tons.

GERMAN NAVAL NOTES.

The Kaiser's Challenge Cups for Prize Firing.—The Imperial challenge cups for the best heavy-gun results at the annual prize firing have been awarded to the battleships *Mecklenburg* and *Lothringen,* for the High Sea Fleet; to the first-class armored cruiser *Yorck* and the small cruiser *Danzig,* for the Scouting Division. The prize for heavy-gun firing for the Coast Artillery has been awarded to the 1st Section of Marine Artillery at Friedrichsort.

The High Sea Fleet has been now reconstituted as follows: Flagship of the Commander-in-Chief, H. R. H. Prince Henry of Prussia, first-class battleship *Deutschland* (Second Squadron).

FIRST SQUADRON.—VICE ADMIRAL VON HOLTZENDORFF, COMMANDING.

First Division.	Distinguishing mark on funnel.	*Second Division.*	Distinguishing mark on funnel.
First-class Battleships—		First-class Battleships—	
Hannover (Flagship of Commander-in-Chief.)	1 White band.	*Wittelsbach* (Flagship of Rear Admiral Ingenohl.)	1 Red band.
Schlesien	2 White bands.	*Wettin*	2 Red bands.
Mecklenburg	3 White bands.	*Ksr. Karl der Grosse*	3 Red bands.
Zähringen	4 White bands.	*Kaiser Barbarossa*	4 Red bands.
		Despatch vessel *Blitz*,	1 White band.

SECOND SQUADRON.—VICE ADMIRAL SCHROEDER, COMMANDING.

Third Division.	*Fourth Division.*
First-class Battleships—	First-class Battleships—
Preussen (Flagship of Commander-in-Chief.) — 1 Yellow band.	*Braunschweig* (Flagship of Rear Admiral Guhler.) — 1 Blue band.
Schleswig-Holstein — 2 Yellow bands.	*Lothringen* — 2 Blue bands.
Hessen — 3 Yellow bands.	*Pommern* — 3 Blue bands.
Elsass — 4 Yellow bands.	Despatch vessel *Pfeil*, 1 Yellow band.

SCOUTING DIVISION.—REAR ADMIRAL VON HEERINGEN, COMMANDING.

First Group.	*Second Group.*
First-class Armored Cruisers—	First-class Armored Cruisers—
Scharnhorst (Flagship of Commander-in-Chief.) — 1 White band.	*Roon* (Flagship of Rear Admiral Jacobsen.) — 1 Red band.
Gneisenau — 2 White bands.	*Yorck* — 2 Red bands.
Second-class Cruisers—	Second-class Cruisers—
Danzig — 3 White bands.	*Berlin* — 3 Red bands.
Königsberg — 4 White bands.	*Lübeck* — 4 Red bands.
Dresden — 5 White bands.	*Stettin* — 5 Red bands.

Under the new organization of the fleet, the first-class battleship *Hannover* has been transferred from the Second to the First Squadron and become the flagship of Vice Admiral von Holtzendorff, commanding the First Squadron, whose previous flagship, the *Wittelsbach,* becomes the flagship of the Rear Admiral commanding the Second Division of the Squadron. All three flagships of the High Sea Fleet—the *Deutschland,* flagship of the Commander-in-Chief, the *Hannover,* and the *Preussen*—are now vessels of 13,200 tons, and the Second Squadron is composed exclusively of ships of this tonnage and is a completely homogeneous squadron. The First Squadron, on the other hand, includes two ships of 11,150 tons, four of 11,800, and two of 13,250 tons displacement; and while the Second Squadron carries twenty-eight 11-inch guns, the First Squadron only carries eight 11-inch guns, with twenty-four 9.4-inch guns.

Launches.—The new first-class battleship *Ersatz Baden* was launched from Krupp's Germania Yard at Kiel on the 12th December, 1908, and received the name of *Posen.* She is the fourth ship for the German Navy of the so-called *Dreadnought* type to take the water during the past year, the other three being the *Nassau,* launched on the 7th of March; the *Westphalen,* on the 1st of August, and the *Rheinland,* on the 26th of September. All that is known definitely about this group of vessels is that they will have a displacement of 18,000 tons, but no other reliable details as to their armor, armament, H.P., and speed have been allowed to leak out.

It is believed that the next group of four, viz: the *Ersatz Beowulf, Ersatz Siegfried, Ersatz Oldenburg* and *Ersatz Baden,* will be larger than their predecessors, as the first vote for these ships, which appeared in last year's Estimates, amounted to £275,000 per ship, as against a vote of only £150,000 per ship for the earlier vessels of the type.

The small cruiser *Ersatz Grief* was launched from the Schichau Yard, Danzig, on the 14th of November, and received the name of *Kolberg.* She is a vessel of 4,300 tons displacement, with turbine engines to develop 20,000 I.H.P., and give a speed of 25.5 knots. The armament will consist of twelve 40-caliber 4.1-inch Q.F. guns, with four 55-caliber 2-inch guns, and two submerged torpedo tubes. There will be an armored deck two inches thick tapering to .8-inch, and the conning tower will be protected by 4-inch armor.

On the 23d ult. was launched from the Vulcan Yard, Stettin, the *Ersatz Jagd,* a sister ship to the *Kolberg.* She received the name of *Mainz;* was commenced in 1907, and is to be completed this year. Like the *Kolberg,* she is to have turbine engines.

On the 29th December was launched from the Germania Yard, Kiel, the Destroyer *G 169,* which is the first of the five vessels of the flotilla of twelve provided under the Estimates of last year building at this yard to take the water. Four other boats of this series are under construction by the Schichau Firm, Elbing, and three at the Vulcan Yard, Stettin.

These destroyers are to have a displacement of 616 tons, but details as to their armament, speed and H.P. are not forthcoming. Five of the boats are to be fitted with Curtis turbines, three with Zoelly turbines, and the other four with Parsons.

New Ships.—The contract for the river gunboat *C* has been awarded to the Tecklenborg firm at Geestemünde, and all the ships of this year's program are now in hand. The gunboat, which is intended for service on the rivers in China, is to be ready by next summer, when she will be transported in sections to Shanghai, where she will be again put together. The first-class armored cruiser *G*, the contract for the construction of which was recently given the firm of Blohm & Voss, Hamburg, is to be fitted with turbine engines on the Parsons' system.

It should be noted that each new series of ships laid down now for the German Navy marks fresh progress, both from the point of view of displacement, power and speed. Thus, the tonnage of the new small cruisers laid down under the program of 1908 is to be increased from the 4,300 tons of their two predecessors to 4,500, while their turbine engines are to develop 30,000 I.H.P., to give a speed of 27 knots, as against the 20,000 I.H.P. and 25 knots of their two predecessors.

Similarly the new destroyers are, it is reported, to have turbine engines developing 14,000 I.H.P., giving a speed of 35 knots, as against the 11,000 and 32.5 knots of their immediate predecessors. These details, however, have not yet been officially confirmed.

Trial of New Destroyer.—The new destroyer *V 161*, built at the Vulcan Yard, has completed her trials successfully. She is the last of the flotilla of twelve vessels ordered under the 1907 program to be completed, and at her full-speed trial attained a maximum speed of 32.14 knots, the mean speed of the remaining eleven being 31.5 knots. All the vessels of this series have a displacement of 680 tons, and are all fitted with Curtis turbines to develop 10,000 I.H.P., the contract speed being for 31 knots.

Floating Docks for Destroyers.—The Howaldt Firm at Kiel has completed two floating docks for destroyers, which have been towed to Wilhelmshaven, where they are to be stationed. These docks are 269 feet long, with a lifting capacity of 1,400 tons, which will enable two destroyers to be docked at the same time. Owing to the bad weather which prevailed, some difficulty was experienced in towing the second dock from Cuxhaben to Wilhelmshaven.

Torpedo Divisions.—Since the addition during the summer of a Fifth Company to the two torpedo divisions, a new half-flotilla (six boats) has been formed from the 1st of last December, so that there are now ten half-flotillas, five in Kiel and Wilhelmshaven, respectively. Out of these, during the next training year, two school flotillas, two reserve flotillas, and a maneuver flotilla will be formed. With the exception of the Second Reserve Flotilla, of which one half-flotilla is stationed at Kiel and the other at Wilhelmshaven, all the flotillas are now composed of large boats (what are generally termed destroyers).

Coaling Times in the High Sea Fleet.—The best record per hour during the past year for coaling out of lighters by the High Sea Fleet is as follows: First Squadron: The *Kaiser Wilhelm der Grosse,* 383 tons, and the *Wittelsbach,* 332 tons. Second Squadron: The *Elsass,* 328 tons, and the *Hessen,* 324. Among the large cruisers the *Yorck* took in 435 tons (the best record of the whole fleet), the *Roon* following with 331. Of the small cruisers, which wheeled the coal on board in barrows from the land, the *Lübeck* took in 260 tons, while the *Hamburg,* with a crew of 172 men all told, took in 525 tons in two hours and a quarter, the average per head in the best hour's working being 1.7 tons.—"J. R. N. S. I."

A TURBINE GASOLINE ENGINE.

This engine is a gas or hydrocarbon type. As shown in Fig. 1 it has an incased flywheel, set between a pair of cylinders, acting as a turbine rotor. Its operation is as follows:

When the first cylinder in a four-cylinder engine is firing the third cylinder is compressing, and just on the point where the compression or resistance is at the highest. The exhaust valve on the first cylinder then opens and the exhaust gases strike the turbine rotor, helping the piston over its compression

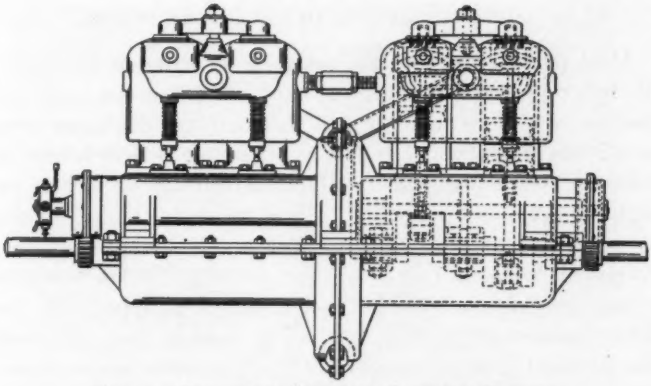


Fig. 1.—Stommel's Turbine Gasoline Engine.

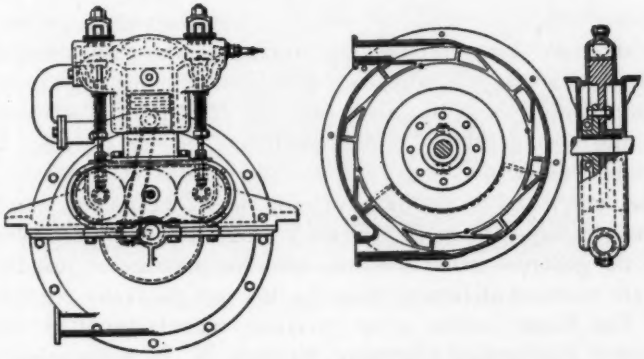


Fig. 2.—End View of Engine and Turbine.

stroke. It is claimed that the turbine rotor revolving so rapidly forms a partial vacuum, thus drawing the exhaust from the engine and relieving it of back pressure.

In Fig. 1 are shown exterior and sectional views of the ar-

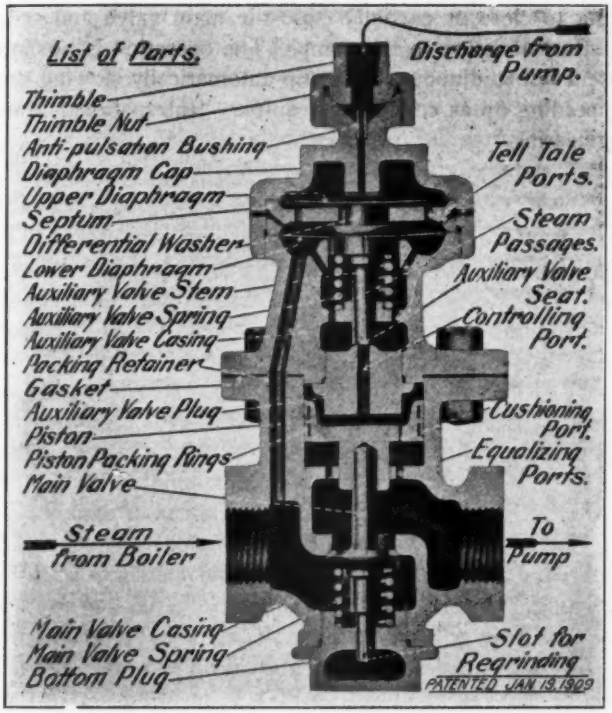
rangement of the cylinder and turbine. Fig. 2 shows end views of the engine and turbine. This combination is the invention of Hugo Stommel, South Elberon, N. J.—"Power and the Engineer."

AN IMPROVED METHOD OF GOVERNING PUMPS.

Most pump governors are designed to maintain the water-discharge pressure at a certain fixed point, but there are numerous conditions under which this uniform discharge pressure is not altogether desirable, as in feeding boilers where the boiler pressure may vary. The disadvantage of a uniform high-feed pressure is readily evident on marine boilers where, say, 250 pounds pressure is carried at sea and perhaps only 80 pounds while in port. In these instances, unless the governors were frequently readjusted, pumps equipped with ordinary governors, would at all times tend to keep the feed-line pressure over 250 pounds. The enormous surplus pressure on the feed line when the boilers were running on the lower pressures would tend to throw the feed water into the boiler with great force, would grind out the valves quicker, would make accurate feeding difficult, and the pumps would race whenever the feed valves were opened. The fireman or water tender must also manipulate the throttle valve oftener, if there were no feed-water controllers on the boilers. It would thus be difficult to maintain the correct water level in the boilers and, in addition to being noisy, the pumps would wear unduly. In cases like this it would be highly desirable if the governor maintained the feed-line pressure at just the right excess at all time to make the flow into the boiler regular.

The Foster excess pump governor, manufactured by the Foster Engineering Company, Newark, N. J., automatically maintains a fixed excess discharge pressure above the boiler pressure regardless of the amount of water being supplied. Referring to the cross section, it will be seen that the governor is provided with two diaphragms, the upper one subjected to the pump-discharge pressure through the connection at the

top of the governor, while the lower diaphragm is in communication with the boiler pressure. Between these two diaphragms is a differential washer, the proportions of which determine the excess of water pressure over the boiler pressure. Reducing the area of the upper surface of this differ-



IMPROVED METHOD GOVERNING PUMP.

ential washer will increase the excess discharge pressure and vice versa. Steam entering the valve passes through the port to the boiler under the lower diaphragm. This tends to raise the diaphragm and allow the upper spring to lift the auxiliary valve off its seat and permit steam to enter the piston chamber, thus forcing down the piston and main valve with which

it is engaged and allowing more steam to pass to the pump. When the pump-discharge pressure passing through the connection in the top of the governor reaches its proportional excess it acts on the upper diaphragm, forcing it down and tending to close the auxiliary valve. The steam pressure on top of the piston is thereby reduced, permitting the lower spring to close or partially close the main valve and reduce the steam pressure to the pump. The operation is not intermittent but continuous, the pump automatically slowing down or speeding up as conditions require.—"International Marine Engineering."

SHIPS.

ARGENTINE.

Argentine Gunboat Parano.—Sir William G. Armstrong, Whitworth & Co., Limited, have now completed the two armored gunboats *Parano* and *Rosario,* for which orders were placed with them by the Argentine Government, and the trials have given results which are consistent with the efficiency invariably achieved by Elswick-built warships.

The dimensions and other particulars of the two ships are as follow: Length over all, 250 feet; length between perpendiculars, 240 feet; breadth, molded, 32 feet 3 inches; mean draught, 7 feet 6 inches; displacement at this draught, 1,000 tons; thickness of armored deck, 1 inch; thickness of protection for guns, 3 inches to 2 inches.

Armament: Two 6-inch howitzers; six 3-inch 50-caliber quick-firing guns; four 75-mm. 12-caliber landing guns; eight rifle-caliber machine guns.

Coal capacity at normal draught, 120 tons.

Complement, 150 officers and men.

The two vessels have been designed primarily for service on the Plate and other Argentine rivers, but their scantlings have been proportioned to enable them to sail the open seas in all weathers. A special feature of the armament, it may be noted, is the adoption of a 6-inch howitzer, in order to give a high angle of elevation to meet certain conditions applicable to the defence of Argentina. The armament otherwise is also of exceptional power for vessels of only 1,000 tons displacement, especially when the adequate protection afforded to all the guns, as well as to the vital parts of the ship, is considered. The offensive and defensive qualities, therefore, give the vessels a high degree of fighting efficiency. The Elswick firm have on previous occasions had to study the necessities of the

wide range of temperature experienced in the Southern Republics, and the cumulative experience of many years has been carefully embodied in these two vessels; this applies not only to the magazine and machinery compartments, but also to the quarters of the officers and men. The accommodation for the commander and executive and engineering officers is arranged abaft the machinery spaces under the poop, and also between the lower and upper decks. The petty officers are housed on the lower deck, immediately forward of the machinery spaces; and the crew is berthed in the forecastle on the main deck. Electricity has been largely applied throughout the ship, and the generating plant has been manufactured at the Elswick Works.

The main propelling machinery has been manufactured by Messrs. Vickers Sons & Maxim, Limited, at their Naval Construction Works, Barrow-in-Furness.

The *Parano* was the first vessel to be subjected to trials. These consisted of a series of progressive speed runs over the Elswick measured mile on the East Coast at about 8, 10, 12 and 14 knots, the trials at each speed extending over three hours. The full-power trial was of six hours' duration, and the speed attained was in excess of that required by the contract, which was 15 knots.

As is almost invariably the case, the second vessel, by reason of the experience gained in the trials of the first, showed still better results, the *Rosario,* on her full-power trial over the measured mile, giving a mean speed of 15½ knots, while during the succeeding six hours the average attained was 15¼ knots. On all the trials the coal consumption was taken, and in this respect also the results were better than those anticipated.—"Engineering."

H. M. Torpedo-Boat Destroyer Nubian.—This vessel, which has just completed her official steam trial, and is one of the last set of 33-knot destroyers given out to various builders last year—the others being named *Crusader, Zulu, Maori* and *Viking*—is the first to be completed, and Messrs. J. I. Thornycroft & Co., Limited, who built the vessel at Woolston, South-

ampton, have repeated the success which characterized their earlier vessels of the type for the British and other navies. The *Nubian* is 280 feet long, and has a beam of 26½ feet. The mean draught is 9 feet 4 inches, and the displacement about 1,000 tons. The hull is built of high-grade steel, galvanized throughout, and the structure is extensively stiffened with special transverse and longitudinal framing, in addition to the watertight bulkheads which divide the hull into compartments. She has a raised forecastle, which, while providing accommodation for the seamen, improves the sea-going qualities of the vessel, enabling her to maintain high speed in "dirty" weather. The chart house and bridge are built at the after end of the forecastle deck, and are at a considerable height above the water level. The chief officers are provided with separate cabins, and there is, as usual, a large wardroom. The electric installation is very complete, and embraces, of course, a searchlight, with a wireless telegraphic installation.

The armament comprises two 4-inch breech-loading guns, and there are also on deck two 8-inch torpedo-launching tubes.

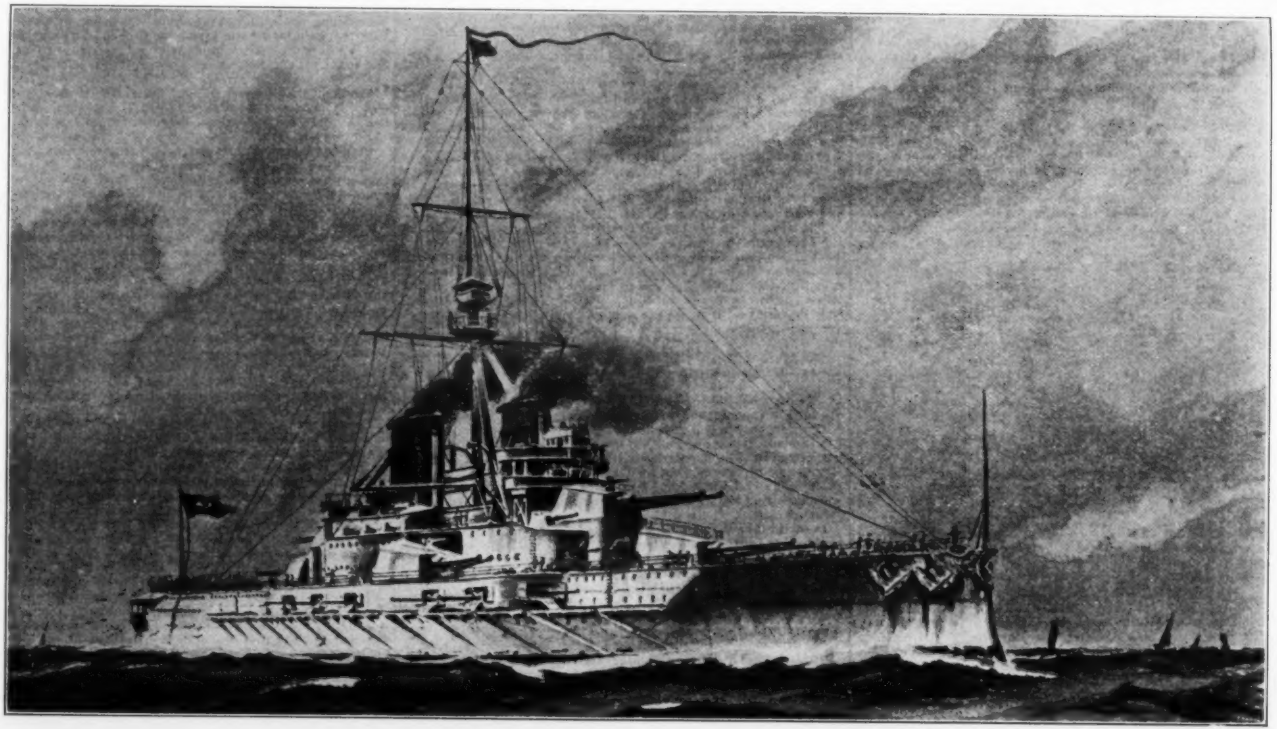
The machinery is of the Parsons turbine type, driving four shafts, each with one propeller, and the boilers are of the water-tube type fitted for oil fuel.

The trials were of an exacting nature. The speed guaranteed was 33 knots, the estimated power for this being 15,500 horsepower. The speed is the same as in the preceding vessels of the class, but the power is 1,000 horsepower greater, due to the increase in displacement, which is over 100 tons when comparison is made with the *Tartar*, a very successful vessel, built by the firm. Notwithstanding the extra load, the trials were as successful as in the case of the *Tartar*, and justify an even greater measure of support by the Admiralty than has recently been given to this well-known firm of pioneers in the building of torpedo-boat destroyers.—"The Engineer."

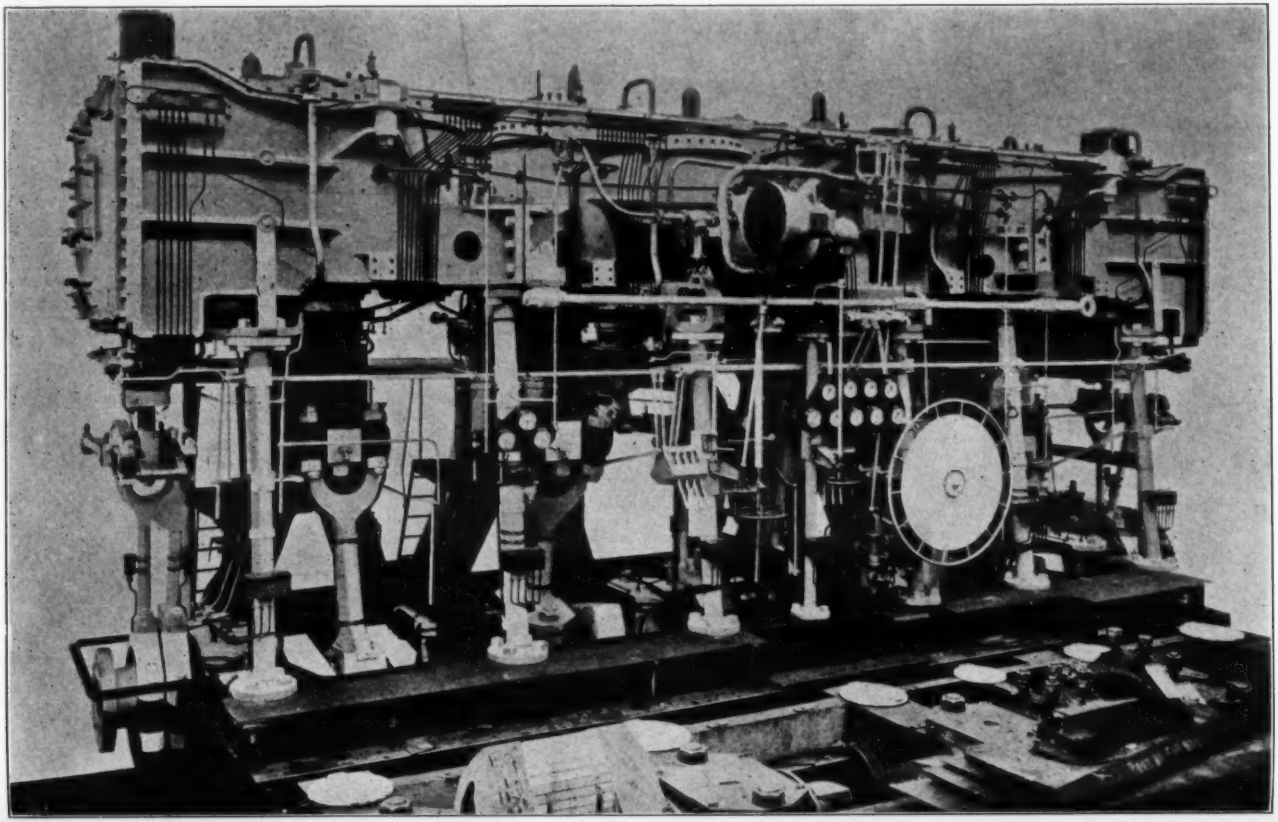
H. M. S. Temeraire.—The steam trials of this vessel have just been completed. The *Temeraire* is the third vessel of the *Dreadnought* type, and embraces all the features that ex-

perience has shown to be desirable. She was built in H. M. Dockyard, Devonport, and is 490 feet long, 82 feet wide, and 27 feet mean draught, 18,600 tons displacement, while the I.H.P. necessary to drive her at the designed speed of 21 knots per hour was 23,000. On trial, both the power and the speed desired were most easily excelled, the vessel proving to be remarkably easily driven, while the boilers easily supplied the steam required. The propelling machinery, with boilers complete, has been constructed by Messrs. R. and W. Hawthorn, Leslie & Co., Ltd., at their St. Peter's Works in Newcastle-on-Tyne. The machinery is of the turbine type, in accordance with the Hon. C. A. Parsons' patents. It was arranged for driving four screws, while the boiler plant consists of an installation of the latest improved large-tube Yarrow-type boilers. The trials consisted of a thirty-hours' cruise at low power; a thirty-hours' trial arranged so that the machinery might be tested at various powers, ranging from the lowest to over 12,000 horsepower; a thirty-hours' trial at seven-tenths the maximum power; and an eight-hours' full-speed trial. During the whole of this steaming the engines and boilers have worked without a hitch, and the results obtained have been of a very gratifying nature, the Admiralty overseers being highly satisfied. In addition to the above, exhaustive stopping, starting, steering and astern trials have been successfully completed, and the vessel has returned to the dockyard for the purpose of making preparations for gunnery tests, which will, it is anticipated, take place in about a fortnight's time.—"Page's Weekly."

Torpedo-Boat Destroyer Swift.—Much interest has been evinced on the Clyde and elsewhere in the speed trials of the new torpedo-boat destroyer *Swift*, built for the British Navy by Cammell Laird & Co., Limited. The trials have been proceeding at intervals on the measured mile at Skelmorlie during many weeks past. This notable vessel, designed, as is generally understood, to be the fastest ship afloat, burns oil fuel, and has four propellers on four shafts, driven by turbines, which have each a supplementary turbine for reversing. Her



FIRST-CLASS BATTLESHIP FOR THE BRAZILIAN NAVY.—"SAO PAULO."



THE PORT ENGINE. FOUR-CYLINDER TRIPLE-EXPANSION TWIN-SCREW ENGINES OF THE BRAZILIAN BATTLESHIP "SAO PAULO."
Constructed by Messrs. Vickers Sons & Maxim, Limited, at their Naval Construction Works, Barrow-in-Furness.

designed average steaming speed at full power is 36 knots, and while great reticence is observed as to the results obtained on her several periods of steaming, with modifications effected on her propellers and condensing arrangements, it appears certain that she has at least reached her guaranteed speed of 36 knots, and this as the average of several double runs over the measured distance. In the intervals between her several periods of trial the vessel has been in the Garvel Graving Dock, Greenock, for alterations to her propellers and hull cleaning, and after one of these dockings, she attained, it is understood, a speed of 36.2 knots on one of her runs. This result is the highest speed ever attained by any vessel on the Clyde measured mile. Meantime, the distinction of being the fastest vessel afloat still rests with the destroyer *Tartar*, built by Messrs. Thornycroft & Co. as one of the 33-knot class, which on her trials steamed at the rate of over 37 knots, and has subsequently, in the hands of Admiralty officials, attained a speed of 38.3 knots, and been credited, indeed, with a speed of 40 knots during a run in the North Sea.—"The Engineer."

THE PORT ENGINE. FOUR-CYLINDER, TRIPLE-EXPANSION, TWIN-SCREW ENGINES OF THE BRAZILIAN BATTLESHIP "SAO PAULO." Constructed by Messrs. Vickers Sons & Maxim, Limited, at their Naval Construction Works, Barrow-in-Furness.

BRAZIL.

Battleship Sao Paulo.—The *Sao Paulo* is 500 feet long between perpendiculars, 83 feet beam, with a displacement of about 19,500 tons on a draught of 25 feet. The speed of the vessel is to be 21 knots, with the engines developing 23,500 indicated horsepower. The coal-bunker capacity is about 2,000 tons, in addition to the oil fuel she carries.

The protection of the vessel marks a considerable advance on earlier practice. The main armor consists of a water-line belt 9 inches in thickness, extending from well below the water line to the upper deck and tapering to 4 inches forward and 4 inches aft. The side armor forms, with the screen bulkheads at the forward and the after ends, a central citadel, the upper deck over which is thickened to form a protective deck. A complete protective deck is also worked all fore and aft in the vicinity of the water line, and a heavy longitudinal bulkhead is constructed on each side of the vessel, enclosing the space

occupied by the propelling machinery, boilers, magazines and shell rooms. Heavy plating is arranged on the main deck outside of the citadel at the forward and the after ends, as well as on the lower deck over the magazines, which, together with the heavy armored screen bulkheads between decks, afford additional protection to the vital parts of the vessel.

The armament consists of twelve 12-inch guns, which are mounted in pairs in six barbettes. The two forward barbettes and the two after barbettes are on the center line; of these four barbettes, the two nearest to the bow and stern respectively are on the level of the upper deck, the two others being on the higher, or boat-deck, level. These latter are raised so that their guns may fire clear over those at the lower level. The midship barbettes are arranged at the level of the upper deck, one on each side of the vessel, the superstructure being recessed to allow of a passageway in the rear of the gun houses at any degree of training. This arrangement of guns allows eight 12-inch guns to fire right aft, and the same number forward, or ten guns to fire on either broadside. The secondary armament consists of twenty-two 4.7-inch quick-firing guns, fourteen of which are mounted behind the protected walls of the citadel on the main deck, seven on each side of the vessel, while the remaining eight are situated in well-protected positions; four being placed inside the superstructure, at the level of the upper deck, and four at the level of the bridge deck. There are also eight 3-pounder guns, which are placed on bridge and gun-house tops, for which special mountings are also provided in the steam and other boats, together with gear suitable for discharging torpedoes.

The guns are served from well-ventilated shell rooms and magazines immediately under them, special cooling plant being introduced for keeping the magazines and the machinery spaces at an even temperature, while the ship throughout is ventilated on a system which allows of either heated or cooled fresh air being delivered to any compartment, and the foul air being withdrawn.

Gun fire is controlled from a platform situated at the top of

the lower steel tripod mast, which is placed between the two funnels, and from which are supported steel derricks, by which the heavy steam and sailing boats are dealt with.

The boat deck, which extends for nearly the complete length of the superstructure, is almost given up to the stowage of the boats in their battle position and to the stowage of hammocks for the crew. On this deck are placed the electric boat hoists and the electric coal hoists.

At the fore end of the boat deck, and rising above it, are the navigating bridge, conning-tower bridge, and range-finder platform, while at the aft end are the observer tower, bridge, and range-finder platforms.

On the bridge deck the cooking kitchens for the officers and the crew, wash places for the crew, &c., are arranged. On the upper deck, inside the superstructure, sanitary arrangements are provided for the petty officers and the crew, while outside the superstructure on the exposed upper deck there are fitted all the latest arrangements for dealing with anchors and cables, &c., and for the mooring of the vessel.

The space aft on the main deck is occupied by the admiral's quarters and accommodation for the officers, a stern walk being provided, which is reached from the admiral's quarters.

The center part of the main deck, which is totally encased in heavy armor, forms the citadel, inside of which are the fourteen 4.7-inch guns already referred to, and in which is provided sleeping and messing accommodation for the crew. Forward of the citadel, on the same range of deck, are the cabins of the warrant officers, the sick bay for the crew and the crew space.

On the middle deck, aft of the armor screen, are the cabins of the ship's officers and engineers, with their mess spaces.

On the lower deck are provided the necessary storerooms, provision rooms, and auxiliary-machinery rooms, while on the platform deck are placed the magazines, capstan-engine room, cold store, steering-gear compartment, fresh-water stowage tanks, &c. The shell rooms and handling room are in the hold.

The vessel is provided with torpedo-net defence, extending for about 350 feet amidships. She is fitted throughout with a complete system of electric lighting, while electricity is largely used as a motive power for auxiliary machinery. She carries six large searchlight projectors, and a flash lamp at the masthead for signalling purposes.

The vessel is also fitted with effective disinfecting and refrigerating plants. She has a complete installation of voice pipes, telephones, and has a wireless-telegraphy apparatus.

Her complement consists of about 900 officers and men.

The propelling machinery consists of two sets of four-cylinder triple-expansion engines, balanced on the Yarrow, Schlick and Tweedy system, each set having one high, one intermediate, and two low-pressure cylinders. The diameters of the cylinders are 39 inches in the case of the high pressure, 63 inches of the intermediate, and 73 inches of each low-pressure cylinder, all having a stroke of 3 feet 6 inches. It is anticipated that the specified indicated horsepower of 23,500 will be developed with the engines running about 140 revolutions per minute, the boiler pressure being 250 pounds per square inch.

The distribution of steam is controlled by a single piston valve in the case of each high-pressure cylinder, double piston valves being provided for each intermediate cylinder, and flat triple-ported slide valves for each low-pressure cylinder, the whole of the valves being actuated by valve gear of the double-bar Stephenson type, and the low-pressure valve gear being fitted in addition with Joy's patent assistant cylinders. Double-cylinder steam engines working "all round" gear are fitted for reversing purposes, and similar engines are provided for turning the main engines.

All the cylinders are separate and independent castings, each being fitted with a separate liner and steam jacketed. The cylinders are supported at the front by wrought-steel pillars, and at the back by castiron columns carrying the guide faces. The bed plates are of cast steel, the bushes being of gun metal lined with white metal, and secured by wrought-

steel keeps. The crank and tunnel shafting is of forged steel and hollow. The propellers are three-bladed, the boss and blades being of manganese-bronze.

The engines are arranged to run inwards when going ahead, the starting platforms being towards the center of the ship, and one condenser being placed on the wing side of each engine room. The total cooling surface of both main condensers is 24,000 square feet. The air pumps are of the independent twin type and are placed one in each engine room.

The boilers, eighteen in number, are of the Babcock & Wilcox latest type, and are arranged in three boiler rooms, the total heating surface being 58,370 square feet, and the grate 1,686 square feet. The supply of air to the stokeholds is provided by ten steam-driven fans, and Weir's pumps supply the boilers with feed water. Ash ejectors and the usual ash hoists are fitted in each boiler room, and there are air compressors for sweeping the boiler tubes and mixing the furnace gases.

A complete installation of evaporating and distilling plant is provided in each engine room, also an auxiliary condenser; while in a separate compartment on the deck above, two cylindrical return-tube boilers provide steam for the auxiliary machinery throughout the vessel for harbor purposes.

The launch was most successful. The weight, including the cradle, was 10,400 tons—never before reached with such vessels. The system was exactly similar to that adopted in connection with the launching of H. M. S. *Vanguard*. The ram abutted against the lower end of a pivoted forged-steel lever, the upper end of which passed through the permanent way and entered, and had a bearing against, a steel-lined cavity on the under side of the sliding way. The exhausting of the pressure water from the cylinder caused the ram to recede and allow the pivoted lever to fall from the vertical to the horizontal plane. Thus the sliding ways were free to carry the ship to the water. The time taken from the first

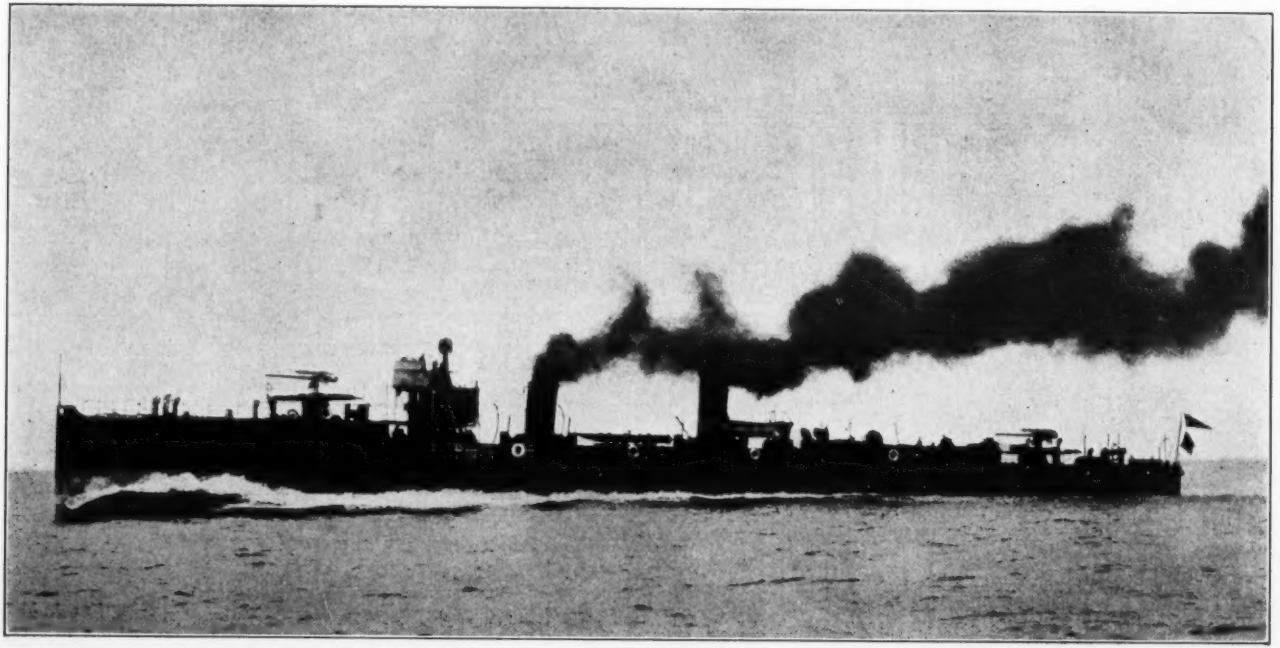
perceptible movement until the ship was afloat was 47 seconds.—"Engineering."

Brazilian Torpedo-Boat Destroyers.—All these ten destroyers are of the same dimensions, viz: 240 feet in length and 23 feet 6 inches beam, and of about 560 tons displacement. They are propelled by two sets of triple-expansion four-cylinder engines, and two double-ended Yarrow water-tube boilers, each boiler supplying steam for about 4,000 indicated horsepower. The vessels are generally similar in appearance to the British "River" class of destroyer, but are a considerable advance on that type as regards speed, the contract being 27 knots as against 25½ knots.

In the matter of propulsive machinery these destroyers possess features which, if not absolutely novel in destroyers, are yet specially noteworthy. A point of outstanding interest is that the Yarrow boilers are fired from both ends, thus making improvements possible in respect of efficiency and favorable working conditions, matters which will afterwards be referred to. For cooling the magazines and the living spaces, the advantage attaching to which, in warm climates especially, cannot be overrated, an efficient refrigerating plant is provided on board. A Marconi wireless telegraphy installation is not the least interesting of the items of up-to-date equipment which these Brazilian destroyers possess.

The armament consists of two 4-inch Armstrong quick-firing guns, one being placed upon the conning tower at the aft end of the forecastle deck, and forward of the navigating bridge, and the other upon a raised platform aft. On the main deck are placed four—two at each side, well amidships—47-mm. Armstrong guns. There are also two 18-inch Armstrong torpedo tubes. For the service of the forward quick-firing gun an Armstrong electric communication hoist is fitted from the forward 4-inch shell room to a convenient position at the back of the gun. The shell room and magazines for the aft 4-inch gun are under the officers' quarters. The ammunition for the smaller guns are handed up as usual.

As regards main structural features the hull of the vessels



BRAZILIAN TORPEDO-BOAT DESTROYER "MATTO GROSSO."
Yarrow & Co., Limited, Scotstoun, Glasgow, Builders.

is built of high-tensile steel wherever longitudinal strength is important. The hull is subdivided into eleven main compartments by ten watertight transverse bulkheads extending from the keel to the upper deck. Below the lower deck there are in addition eight subdivisional bulkheads, the destined purpose of each compartment being as usual in this class of vessel. There is a watertight compartment at the fore end, of which absolutely no use is made in the working economy of the vessel. Behind this is the chain locker, and the third and fourth compartments are occupied as firemen's and crew's quarters. Below these are the electrical, naval and gunners' stores, the main magazine for torpedoes, the magazine and shell room for the 4-inch guns, the magazine for the 47-mm. gun, the provision room, fresh-water tank, &c. The boilers occupy the fifth and sixth compartments, a cross coal bunker being situated at the forward end, and wing bunkers at each side of both boiler rooms. In the compartment containing the engines for propulsive and other purposes, the disposition of the various accessories is so arranged as to bring the items under easy and effective control of the engineers in charge. Leading out of the engine room is an access door to a compartment containing various auxiliary machines, and underneath this is a compartment devoted to engineers' stores. In this compartment attention can be given to the glands of the shafting.

Abaft of this, and with the exception, in the lower parts, of the aft 4-inch shell room, magazine, and the magazine for small-gun ammunition, captain's store, wardroom store, and higher up at the very stern, the bread and other storerooms, all the space is occupied as officers' accommodation. This consists of a wardroom, aft, measuring 14 feet long by 21 feet wide, having accommodation for ten officers, and with a pantry adjoining. The furniture in the wardroom and all the officers' rooms is of polished mahogany; but here it may be stated that the fittings in all other living spaces and in storerooms are made of metal wherever possible to minimize risk of fire. Expanded metal for vertical erections, such as bins, is much in evidence, and perforated sheet and wove netting for hori-

zontal shelves, berths, &c. The decks are covered with cocoanut matting and the floors of the living spaces with "Cortocine," affording both lightness and good foothold. On the starboard side is the captain's cabin—a roomy and well appointed apartment. On the port side of the wardroom passage are three roomy double-berth cabins for officers, all being about 8 feet square. Side lights are, of course, fitted into all these rooms, and a skylight is provided over the center of the wardroom. All the above mentioned living rooms are provided with a supply of cool air from the refrigerating plant in the engine room.

Forward, on the upper deck, on the starboard side, a separate apartment is divided off from the rest of the living spaces there for six engineer officers, and another separate cabin for four petty officers. On the port side a separate two-berth cabin is arranged as a sick bay. Roominess and general comfort, consistent with the special objects in view in the design and service of these vessels, characterize the living accommodation.

At the forward end of the boiler casing on the upper deck is the cooking galley, and above this is the chart house, immediately behind which and with separate access is the Marconi telegraph station, the sides, floor and roof of which are completely insulated with 3-inch cork. The forecastle deck is extended aft beyond the conning tower and gun platform, so as to afford direct communication with the chart house. Above the latter is the navigating bridge, with Chadburn's telegraph, Lord Kelvin's compass, Siemens searchlight, &c.

There are two Yarrow water-tube boilers fired from both ends and designed for 8,000 collective indicated horsepower. Each of them is placed in the mid-length of their respective compartments, thus providing four stokeholds, each of which is fitted with a fan for forced draft driven by an enclosed engine having forced lubrication made by W. H. Allen & Son, Bedford. For dealing with the feed water there is installed at the aft end of each boiler room one of Weir's auxiliary feed pumps.

The twin sets of main engines are of the four-cylinder triple-expansion design, balanced on the Yarrow, Schlick and Tweedy principle, the order of the cylinders, named from the forward end, being: Low-pressure, high-pressure, intermediate and low-pressure. The valve gear is of the usual link-motion type, having twin-bar marine-pattern links, all parts liable to wear being so constructed as to facilitate adjustment. All-round reversing gear for both steam and hand control is fitted. Each engine has an air pump, worked by rocking levers and links off the forward low-pressure crossheads.

The condensers, which are snugly disposed in the wings, are of brass alloy, and have brass tubes. A circulating pump and engine of Yarrow's own make, placed at the forward end, circulates water once through each condenser. Instead of auxiliary air pumps being provided, two small steam ejectors are fitted, with suctions connected to each condenser, so that with a few of the auxiliaries running the condensers can be kept drained when the main engines are not working. Two large combined feed filters and hotwells, one for each set of main engines, are placed at the forward end of the engine room, and into these filtering hotwells the discharge is taken from the main air pumps, any grease or impurities being intercepted by flannel-covered screens of suitable surface and thickness. A Weir's main-feed pump fitted on the outboard side of each of these wells draws from them and delivers straight to the boilers without the usual intervening feed-regulating apparatus. Besides being an extra complication, even the best of automatic feed regulators is apt to become a source of danger under given circumstances. This is so through the risk of the apparatus sticking when the rate of evaporation is suddenly varied from that at which the regulator has been set to deal. If conjoined to this there is inattention to the state of the water gauge on the part of those in the stokeholds, relying, as they perhaps have some right to do, on the proper working of the regulator, very serious trouble will most likely result. The feed in the boilers of these destroyers is controlled by a hand valve fitted on the discharge side of the feed-heaters, and by

this means no difficulty whatever is experienced in keeping a proper working level in the boilers.

Other auxiliary plant fitted in the engine room are an evaporator and distilling apparatus of Caird & Rayner's make placed at the forward end, and also a fire-and-bilge pump, and at the aft end the refrigerating plant, consisting of a Hall's No. 5 carbonic-anhydride machine, by which the magazines and crew's spaces are kept cool. For this latter purpose the machine works in connection with two thermo-tanks by the Thermo-Tank Company, one situated in the officers' quarters aft and the other in crew's space forward. The pumping arrangements throughout these destroyers consist of steam ejectors and hand pumps, supplemented by bilge circulation from the main circulation pumps in the engine room.

In the special auxiliary room, aft of the main engine room, and having ready access from the latter, are fitted the air compressor of Brotherhood's make for charging the torpedoes; and the steam-steering engine of Napier Brothers' geared, vertical, wall design. This is connected by miter wheels and shafting to the steering wheel on the navigation bridge and to one in the conning tower, the wheel aft being actuated by hand. In the auxiliary engine room also is the combined dynamo and engine of the Siemens-Brotherhood type supplying current for all purposes on board. Under the auxiliary engine room is the stern gland compartment, which is also fitted as an engineer's storeroom. All the necessary tanks for oil and waste, racks for spanners and other tools, and most of the engineers' spare gear are arranged in the main engine room.

A distinct feature of the Yarrow double-ended boiler is the complete separation of the back and front furnaces from each other by a transverse dividing firebrick wall, built round and between Field tubes radiating from the steam drum, the tubes in this way while forming a substantial support for the wall, are at the same time protected from the highest temperature of the furnaces. The wall is built up to the under side of the steam drum, and out at each side. The lower part of wall is built hollow, and arranged so that the air, which is admitted

over the fires, passes on its way to the furnace, through this hollow space, and becomes heated before reaching the air nozzles of the furnace. At the bottom end of each of the Field tubes screw caps are provided for cleaning purposes, and are so placed as to be of easy access. All that is required is removal of the handhole doors fitted on the plates forming the bearer for the center brick walls. Safety air doors and protection boxes are provided, so that in the event of a tube bursting it is not possible for steam and flame to enter the stokehold.

One advantage of the boiler arrangements in these vessels will be readily apparent. This is the reduction of complication in the matter of boiler mountings, pipes and fittings. The main and auxiliary steam stop valves, feed valves, scum valve, blow-out valve and water gauges are only necessary at one end of the steam drum. Had boilers of the usual type been fitted, these connecting pipe, joint and other fittings would have been duplicated, and entailed a greater number of steam and feed joints to maintain in an efficient condition.

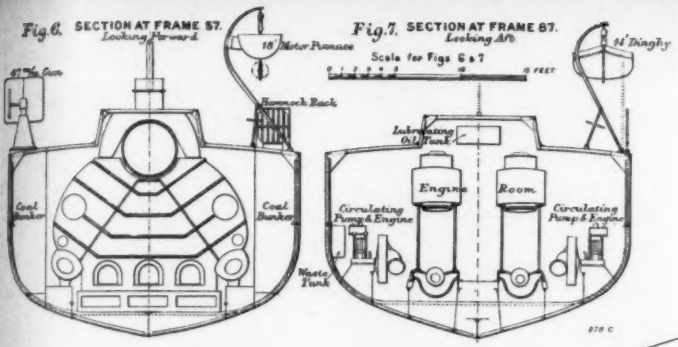
Other outstanding advantages of the arrangement may be referred to. There is a saving in overall length of boilers amounting to at least 10 per cent. With boilers fired from both ends weight is saved in that there are only two steam-drum ends and four water-pocket ends, against four of the former and eight of the latter, where two boilers of the usual type are installed. Each boiler being in one compartment—so to speak, in the middle of one stokehold—there is a cool bulkhead behind the firemen in every case. This, combined with the saving in length, enables the stokeholds to be exceptionally large and cool. With a common stokehold between two boilers, it is impossible for the firemen to find a place away from the heat radiation of the furnaces in front of them and behind them. In a tropical climate especially, and bearing in mind the arduous and difficult work that has to be done in a destroyer stokehold, it is scarcely possible to overestimate the advantages—as regards the comparative comfort and resulting effi-

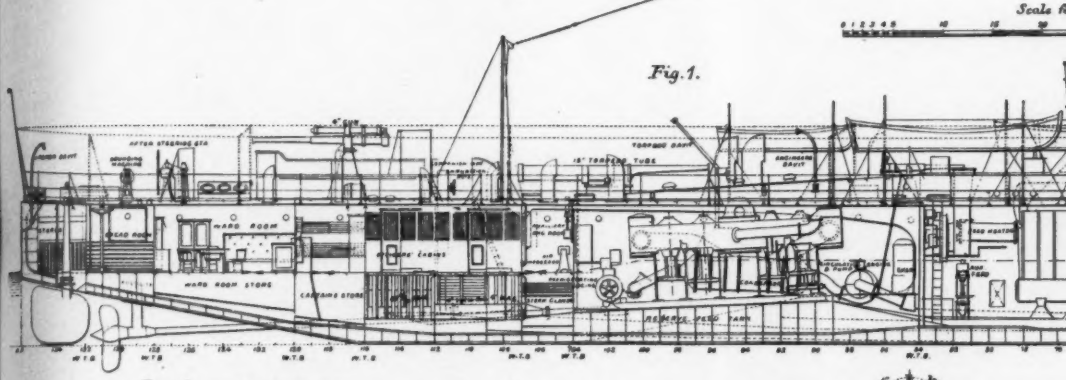
ciency of the staff of the stokeholds—made possible by the adoption of these double-ended boilers.

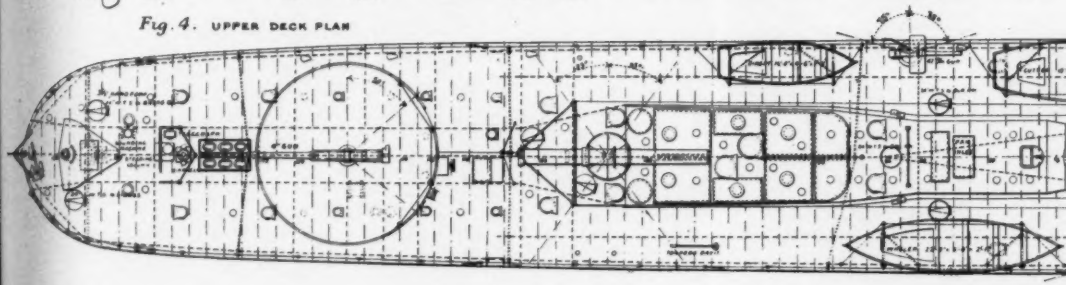
The simplicity secured by abolishing about half of the usual amount of steam and feed connections, and the reduction of the number of joints and valves claiming the engineers' attention, is supplemented in boilers of this type by the simplicity of the uptakes, it being possible, in fact, to reduce the number of funnels without the necessity of long or one-sided uptakes. Besides, by these means the area exposed to shot is materially reduced.

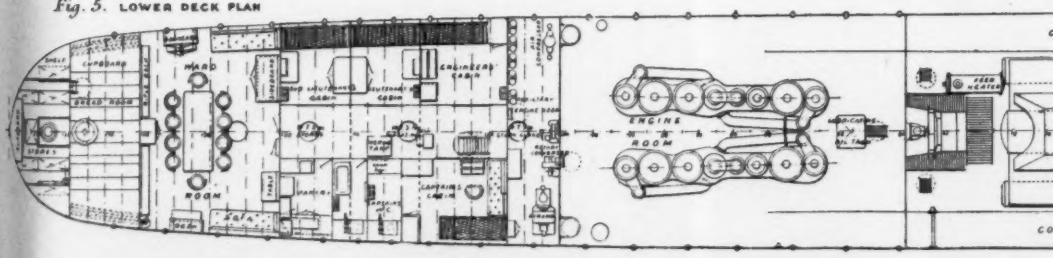
Owing to the large capacity of the steam drum, the variations in water level and steam pressure are reduced, and from experience gathered on the long voyages made by these vessels, this is an important gain, for it is well known how much better results can be obtained, both as regards economy and speed, if the steam and water are steady. Easy accessibility to all parts, even when steam is up, is not always secured with single-ended boilers, placed back-to-back, or when their backs are in proximity to a bulkhead. Ease in getting to the boiler all round is a great factor in prolonging its life, as any trifling defect such as painting is not neglected. Still further advantages may just be mentioned. The center of gravity is slightly lowered, and the economy is increased, due partly to reduced surface for radiation. All the advantages enumerated, we think, go to make this boiler a distinct advance over the single-ended boiler. As a proof of the economy, it will be of interest to mention the result of the official eight-hours 14-knot consumption trial, carried out with the *Para* in the estuary of the Clyde. This vessel ran 26.377 knots to the ton of coal, which gives her a radius of action of 3,692 knots.

The provisions made to guard against and minimize the extreme heat to which these destroyers will often be subject are as thoroughly thought out in connection with the living accommodation, and with keeping the magazines cool, as has been shown to obtain in the machinery departments, with their ample space and mechanical as well as natural means of ventilation. The cowl ventilators throughout are much larger



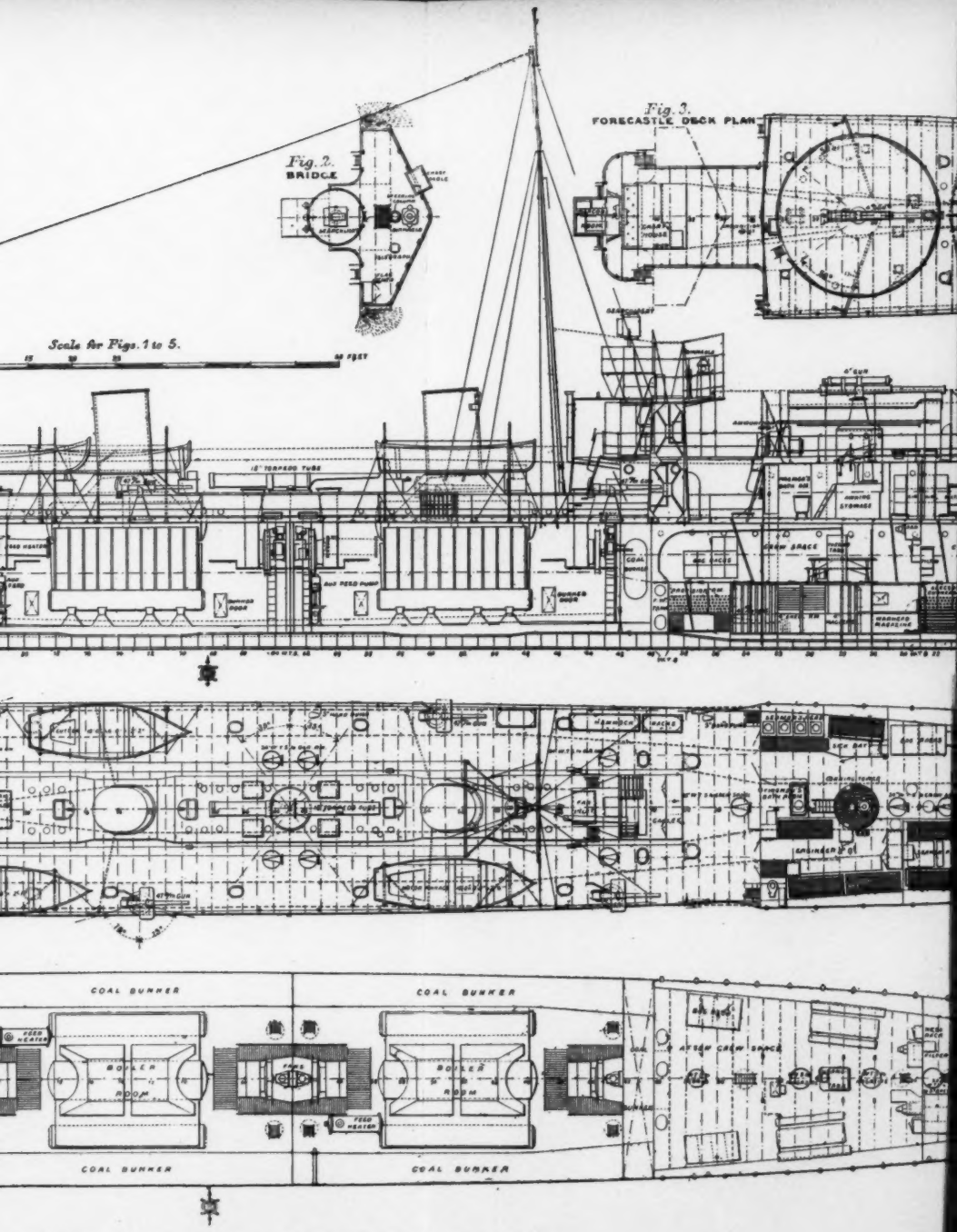






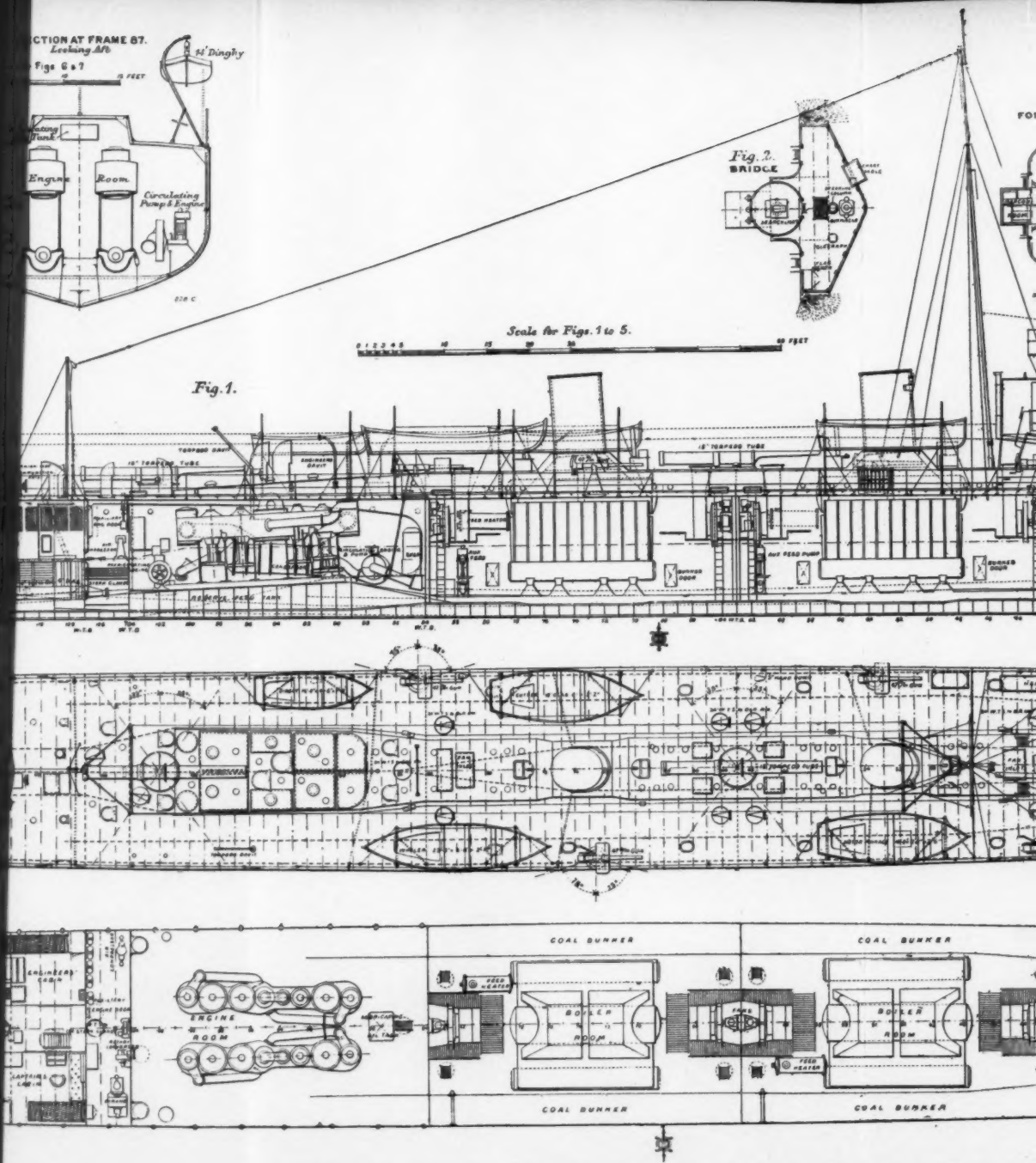
THE TORPEDO-BOAT DES

Constructed by Messrs. Yarrow &



BOAT DESTROYER "PARA," FOR THE BRAZILIAN NAVY.

Yarrow & Co., Limited, Shipbuilders and Engineers, Scotstoun, Glasgow.



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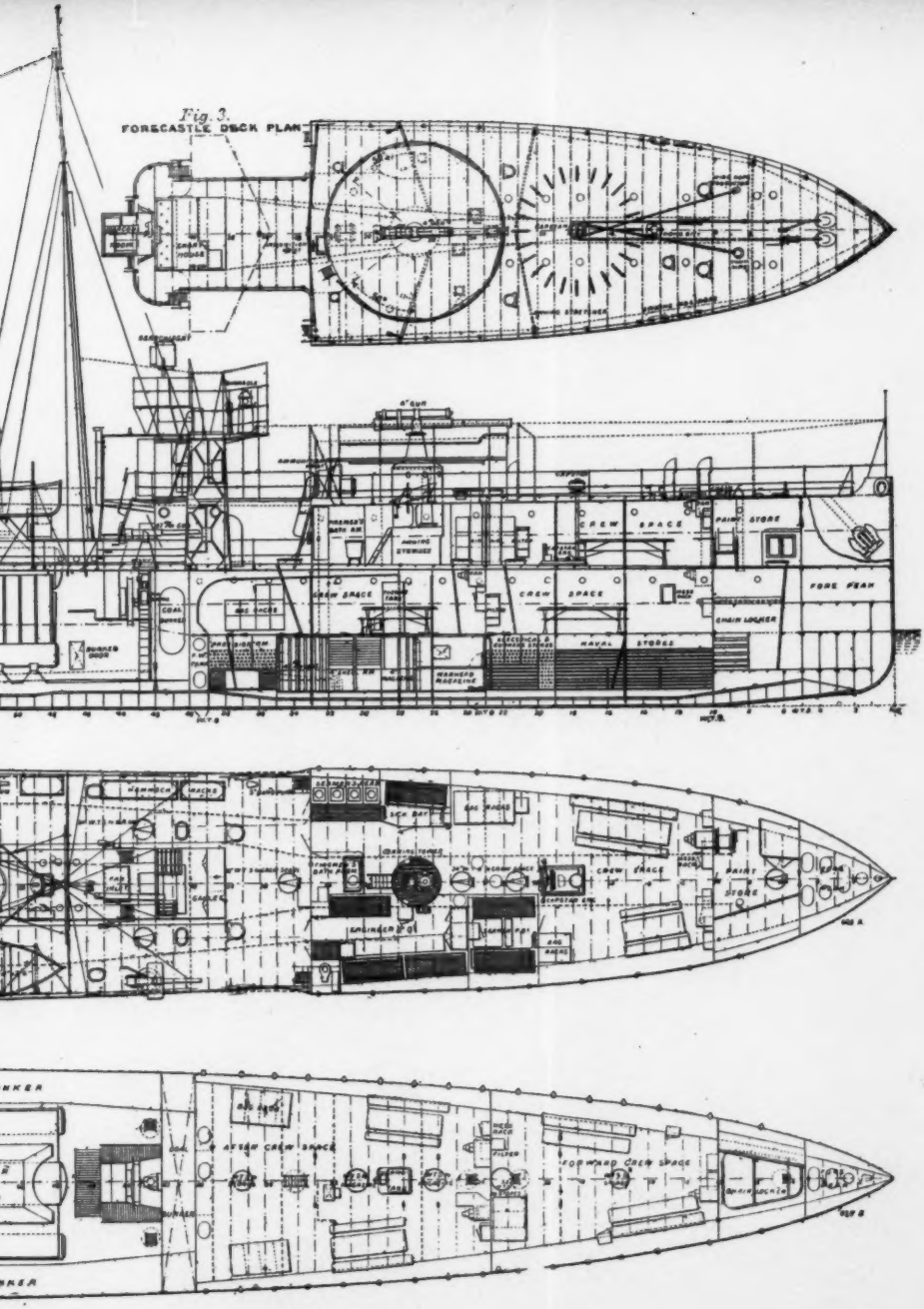
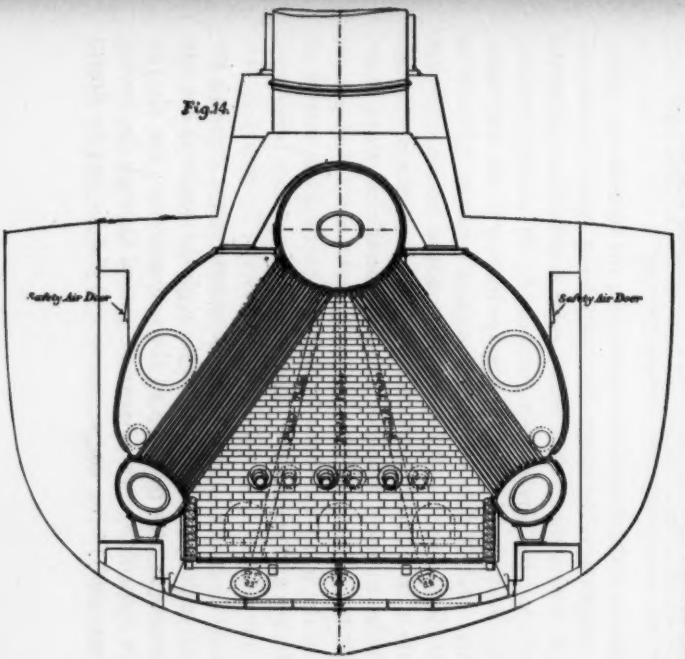
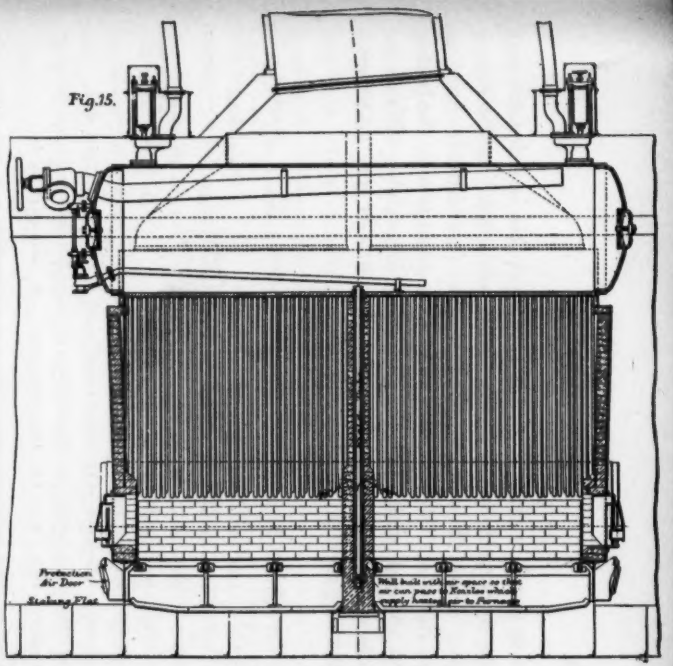


Fig. 3.

AN NAVY.

stoun, Glasgow.





DOUBLE-ENDED YARROW WATER-TUBE BOILERS FOR THE BRAZILIAN TORPEDO-BOAT DESTROYER "PARA."

Constructed by Messrs. Yarrow & Co., Limited, Engineers and Shipbuilders, Scotstoun, Glasgow.

than is usual in vessels of this type, and this is a feature applying more particularly to the means for ventilating the stokeholds. Here the air supplied to the forced-draft fans is taken in through doors in the top of the casings over the boiler room, instead of through the customary big cowls—difficult to handle and easily damaged—whereby little if any additional duty is imposed on the fan engines.

No.	Hour.	Boilers.	Vac.	Air.	Revs.	Time.	Speed.	Means.	2d means.	Remarks.
1	11'1	215.0	26.10	1.75	336.5	2-12.5	27.169			Going north.
2	11'10	210.0	26.10	1.62	335.5	2-12.0	27.273	27.221	27.257	
3	11'20	215.0	26.25	1.81	340.5	2-11.8	27.314	27.293	27.366	Advance per rev.: = 8.179 feet.
4	11'29	215.0	26.0	1.68	341.0	2-10.6	27.565	27.439	27.491	
5	11'39	217.5	25.87	1.62	340.5	2-10.8	27.523	27.544	27.460	
6	11'48	210.0	26.0	1.75	335.75	2-12.2	27.231	27.377		Going south.
Mean of miles		213.75	26.05	1.70	Mean of means of revs. 339.801; speed 27.411; slip 16.01 pr. ct.					
For two hours		210.5	25.94	1.62	Mean revolutions, 335.28; mean speed, 27.061.					

The total revolutions for two hours, 80,467 (being 40,234 starboard and 40,233 port), which × advance per revolution and divided by 2 = 54.1233 knots + 27.411 knots for the first hour = a mean of 27.1781 knots mean for the three hours. Everything worked well.

The thermo-tank system of providing for suitable and agreeable temperature in magazines and living spaces merits, of course, some notice. The Hall's refrigerating machine in the engine room has already been mentioned. Of the two thermo-tanks, one is placed aft in the passage leading to the wardroom and the other in the second crew's space forward. The brine pipes connecting the refrigerating machine to the forward thermo-tank are very heavily insulated where they pass through the boiler rooms. The cool air from the thermo-tanks is delivered by the electrical fan of each tank into the magazines or into the living quarters through a very complete system of trunkways and controlling valves, the arrangement being such that any of the three following results can be obtained, viz: the air (1) can be drawn from the compartment in which the thermo-tank is situated, passed through the cooler down into the magazine and returned to the compartment; the air (2) can be drawn from the magazine, passed through the cooler, and returned to the magazine; or (3) the air can be drawn

from the compartment in which the thermo-tank is placed, passed through the cooler and delivered into the various officers' rooms and crew's spaces. The several principal magazines for torpedo heads and gun shells, both forward and aft, are thickly insulated with cork and felt and thoroughly lined with teak. By this means when the refrigerating machine has sufficiently reduced the temperature in the magazine the same may more easily be maintained.

One item in the equipment of these Brazilian destroyers is a novelty so far as this class of vessel is concerned. This is a motor pinnace, for which, no doubt, important uses will be found in the course of service. This little craft—there being three other boats to the equipment of each of the destroyers—is 18 feet in length, and is, of course, carried inboard on davits, the weight being well under a ton. While weight is kept down to a minimum, the craft are able little sea boats, with good freeboard, and built on the carvel system with wood of fairly stout scantling. All the motor pinnaces for the destroyers are propelled by 8-H.P. paraffin engines, and have reversible propellers. In connection with these little vessels, it is worthy of note that the firm which has built and is building them—McLaren Bros., Dumbarton—is also to provide a motor tug boat for use in towing the pinnaces.

Mention has been made of the fact that in the case of the *Para's* trials on the Clyde the vessel ran 26.377 to the ton of coal, giving her a radius of action of 3,692 knots. Other vessels of the series have shown equally good results, and subjoined is the tabulated results as to steam, speed, etc., of the trials over the measured mile at Skelmorlie of the *Amazonas*, made on 29th December.—"Engineering."

FRANCE.

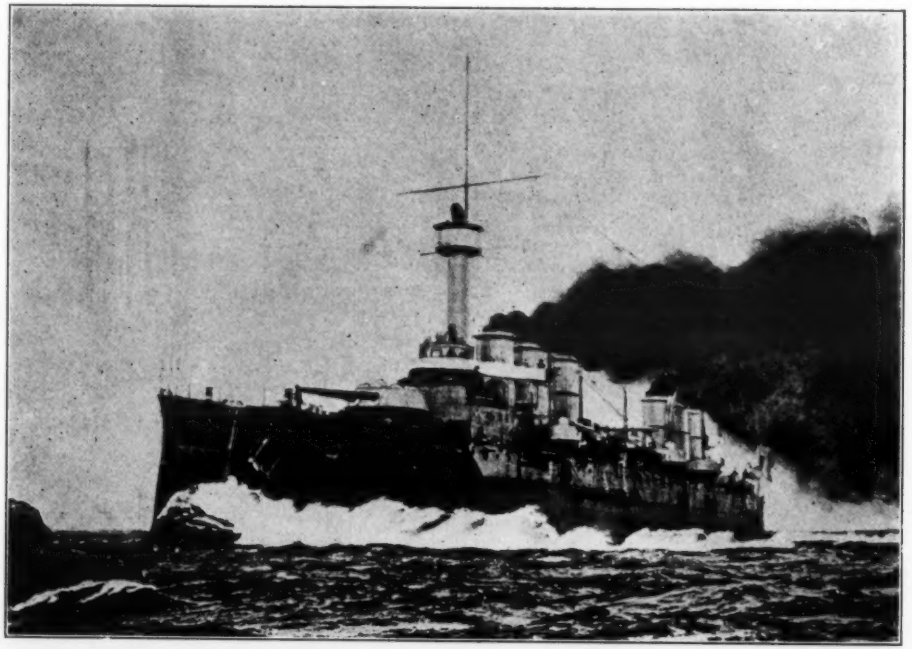
Armored Cruiser Ernest Renan.—Although authorized in the French naval program of 1900 and contracted for in August, 1903, yet, due to the many changes in design made by the Admiralty, the *Ernest Renan*, the first of the 23-knot French cruisers, was not completed until April, 1908, and her

official trials were not carried out until the latter part of the same year. The *Ernest Renan* is 515 feet 2 inches long on the waterline, with a beam of 70 feet 1 inch, and, at a draught of 26 feet 10 inches, displaces 13,644 tons. Three triple-expansion engines, aggregating 37,000 horsepower, were designed to drive the ship at a speed of 23 knots.

The hull is built of the highest quality mild steel, and there is no metal keel, simply a docking keel of teak and two bilge keels, extending for about three-fourths of the ship's length amidships. The stem is of forged steel and the stern frame of cast steel. From the bottom of the ship to the lower protective deck the hull is divided into numerous main compartments, many of which are subdivided into smaller watertight compartments. The double bottom extends to the protective deck. The shell plating is 11/16 inch maximum thickness below the waterline and 13/32 inch above the waterline. The plates are worked according to the double-clincher, double-garboard and two-strake system.

As is the custom on all French warships the armor is arranged according to the "tranche cellulaire de protection" system, which consists of side armor and lower and upper protective decks. The highest point of the lower protective deck is a little above the load waterline. At the sides it is 4 feet 7 inches below this level. It is built of 1.4-inch mild steel plates, protected by 1.8-inch nickel-steel armor on the flat and 2.6-inch nickel-steel armor on the slopes. The upper protective, or splinter, deck is at the height of the upper edge of the second strake of side armor. It is built of steel plates from 1.4 inches to 13/32 inch thick.

There are three strakes of side armor, the first and second of which extend from the stem to within a few feet of the stern, terminating at an athwartship armored bulkhead. The belt extends 4 feet 7 inches below the normal waterline and 17 feet 1 inch above the waterline forward and 7 feet 7 inches above it aft. The first strake is 6.7 inches thick forward reduced to 4 inches aft. The second strake is 5 inches thick forward reduced to 3.6 inches aft, while the third strake extends



THE "ERNEST RENAN" AT FULL SPEED.

from the stem 122 feet aft, or up to the casemates of the forward 6.5-inch guns; thus it will be seen that there is ample protection for the bow of the ship. The athwartship armored bulkheads extend from the outside plating of the casemates to the 7.6-inch turrets, and as an additional protection a cofferdam extends the entire length of the ship at the waterline.

With the exception of the spardeck, all decks are clear from all the ordinary auxiliary apparatus which was formerly found on all French warships. This is worthy of note, because it shows the new policy inaugurated by the Admiralty. Between decks the vessel is roomy and well fitted out.

The armament consists of four 7.6-inch guns mounted in pairs in turrets, one forward and one aft of the superstructure, each having a total arc of fire of 228 degrees. There are twelve 6.4-inch guns, eight of which are mounted single in turrets on the spardeck, four on each side, the remaining 6.4-inch guns being located in four casements, two forward and two aft. The secondary armament consists of sixteen 2.6-inch rapid-fire guns, of which twelve are located in the broadside battery and the remainder on the bridges. There are also four 3-pounder guns and two 18-inch submerged torpedo tubes. The fore-and-aft fire consists of two 7.6-inch guns and six 6.4-inch guns, while for the broadside fire four 7.6-inch and six 6.4-inch guns are available. The 7.6-inch turrets are protected by 8-inch armor and the barbettes with 5-inch armor, while the smaller turrets are protected by 5.5-inch armor. The casemates are protected by 5-inch armor.

The cruiser is propelled by three main engines of the four-cylinder triple-expansion type, located in three watertight compartments amidships. The cylinder diameters are: high-pressure, 45 inches; intermediate, 68 inches; low-pressure, 78 inches. The stroke is 42 inches and the revolutions per minute at full speed 133. The order of the cylinders from the forward to the after end is low-pressure, high-pressure, intermediate-pressure and low-pressure. There are three reversing engines, one of the usual type, another of a special type, and a third operated with oil. Each engine has two separate

condensers with auxiliary apparatus in a special watertight compartment, while between the condensers are the thrust blocks.

Steam is furnished by forty-two Niclausse watertube boilers, located in watertight compartments containing batteries of eight each. Part of the boilers are forward and part aft of the main engines. The products of combustion escape by means of six funnels, 91 feet high above the grate bars. The boilers are 7 feet 6 inches long, containing a total of 14,526 tubes, the upper ones beng 2 15/16 inches inside diameter and the lower ones 3 1-16 inches inside diameter. The working steam pressure is 299 pounds per square inch, the total grate area 2,780 square feet, and the total heating surface 84,620 square feet. The boiler rooms are supplied with fresh air by electric fans and by steam-driven fans for forced draft. The ashes are removed by means of electric winches.

The total capacity of the coal bunkers in 2,300 tons, the normal supply being 1,524 tons, the steaming radii at 10 knots under those conditions being, respectively, 12,000 and 7,500 miles. At full speed the steaming radii are 1,650 and 1,028 miles, respectively.

The auxiliary machinery includes four dynamos, located in two separate watertight compartments on the lower protective deck. These dynamos operate at 110 volts, and have a capacity of 1,200 ampères each. All apparatus, except that requring excessive power, is driven by electricity. The turrets, ammunition hoists, ventilating fans, with the exception of the forced-draft blowers, are all electrically driven. There is a complete refrigerating plant for the magazines, which are close to the boiler or engine rooms. The distilling apparatus has a capacity for 35,000 gallons of fresh water per day.

If the *Ernest Renan* is compared with similar ships of the leading naval powers which were designed or laid down at the same time, it is easily seen that in the matter of armored protection she is superior to any other ships. As far as thickness of armor is concerned, assuming that the quality is the same on all the ships, the *Warrior* and *Minotaur* of the English

Navy have a slight superiority. The German type, although protected to an extreme height amidships, has no efficient protection fore and aft. The *Tennessee* of the United States Navy has a better protected surface, but it is to be regretted that she has not been given better protection forward, as this will cause a certain inferiority in an engagement, because the bow is a vital part of a ship which is built for speed. It is distinctive of the French type that the bow of the ship is given ample protection far in advance of that provided in any other navy.—J. G. Peltier, in "International Marine Engineering."

ITALY.

Battleship Roma.—The dock trials of the last of the 12,500-ton Italian battleships of the *Vittorio Emanuele* class have recently been completed. This ship is the *Roma,* which was launched April 21, 1907. The other battleships of the class, which are already in commission, are the *Vittorio Emanuele, Napoli* and *Regina Elena.* The principal dimensions of the *Roma* are as follows: Length over all, 474 feet 6 inches; length between perpendiculars, 435 feet; beam, extreme, 73 feet 6 inches; draught, mean, trial, 25 feet 9 inches; displacement, trial, 12,625 tons; launching weight, 6,000 tons; coal supply, normal, 1,000 tons; coal supply, maximum, 2,000 tons; steaming radius at 10 knots, 10,000 miles; estimated speed on trial, 21½ knots.

The hull is of steel throughout, and the stem and stern posts and propeller brackets are of cast steel. The armor, which is face-hardened, is distributed as follows: A 10-inch waterline belt extending the length of the machinery space, tapering to 4 inches at the ends; a central redoubt of 8-inch armor and a 3⅛-inch protective deck, worked in forward. The large turrets have 10-inch armor and the smaller turrets 6-inch armor.

The armament consists of two Armstrong 12-inch, 40-caliber, 51-ton guns, mounted on the centerline of the ship, one forward and one aft. Each gun has an arc of fire of 300 degrees, and fires a charge of powder weighing 450 pounds and a projectile weighing 850 pounds, capable of perforating

13 inches of Krupp armor at a distance of 2,000 yards. The rest of the main battery consists of twelve 8-inch Armstrong 45-caliber, 19½-ton guns, mounted in pairs in turrets amidships. These guns fire a projectile weighing 230 pounds, and are capable of perforating 7 inches of Krupp armor at a distance of 8,860 feet.

The secondary battery consists of eight 3⅛-inch, 40-caliber guns; four mounted in barbettes, two at the bow and two at the stern, the remaining four being distributed in commanding positions at the sides. There are also twelve 1⅞-inch rapid-fire guns, four canister guns and two 3-inch landing pieces. The total weight of the bow or stern fire is 2,554 pounds, while the total weight of the broadside fire per minute is 3,042 pounds.

It is noteworthy that the 6-inch guns usually employed for the secondary battery on Italian battleships are absent in the *Roma*. It is claimed by Mr. Cuniberti that, since the 6-inch guns can penetrate only 3 inches of modern armor at a range of 3,000 yards, this gun is ineffective against highly-armored vessels at probable battle ranges, while for the chief work for which they would be used—that is, driving off torpedo boats and small craft—the 3-inch guns are almost equally effective.

The *Roma* is propelled by two sets of triple-expansion engines, designed to develop 20,000 indicated horsepower, giving the ship a speed of 21.5 knots. Steam is supplied by fourteen Babcock & Wilcox water-tube boilers. With a bunker capacity of 2,000 tons of coal the estimated steaming radius at cruising speed is 10,000 miles. Electricity is used throughout the vessel for lighting, steerage, hoisting ammunition and operating the turrets.—Dagnino Attilio, in "International Marine Engineering."

MERCHANT SHIPS.

The Japanese Volunteer Turbine Steamer Sakura Maru.—During the Russo-Japanese War the want of Japanese merchant steamers adaptable as auxiliary cruisers was fully recognized, and the lesson was subsequently forced home by the Imperial Marine Association, founded in 1899, under the patronage of H. I. H. Admiral Prince Arisugawa. The result of the efforts of this association was the founding, in 1905, of the Imperial Volunteer Fleet for the organization of auxiliary cruisers which could, to some extent, be self-supporting as merchant ships in times of peace. Upon the advocacy of Baron Goto, the Minister of the Communication Department, then the Viceroy of Formosa, the Formosa Vice-Regency promised to grant the yearly subsidy of £26,000, on the condition that the first steamer built should run between the mainland and Formosa. More than half the fund for the first steamer was raised among the Formosans. The order for the first steamer was placed with the Mitsu Bishi Dockyard and Engine Works in May, 1906, the vessel was completed in October, 1908, and now the management, during peace, has been entrusted to Messrs. Osaka Shosen Kaisha, who have run the steamer as a mail and passenger express ship between Kobe and Keelun from the beginning of the year, under the auspices of the Formosan Vice-Regency.

This vessel is interesting, not alone because she is the first of the Japanese Volunteer ships, but because she is the first ship fitted with turbines made in Japan. The particulars of the vessel are as follows:

Length between perpendiculars, 335 feet; breadth, 43 feet; depth, 31 feet 6 inches; gross tonnage, 3,200 tons; draught, 17 feet; displacement, 3,880 tons; horsepower, 8,500; speed on trial, 21 knots; machinery, Parsons marine turbine; boilers,

Miyabara water-tube. Number of special first-class passengers, 4; number of first-class passengers, 28; second-class passengers, 42; third-class passengers, 240.

The *Sakura Maru* has a cut-water stem, elliptical stern, two pole-masts, with small signal yard on the fore mast, and two elliptical funnels. The rate of speed being high, the lines of the vessel were made very fine, and, with her graceful shear, she presents a very smart appearance.

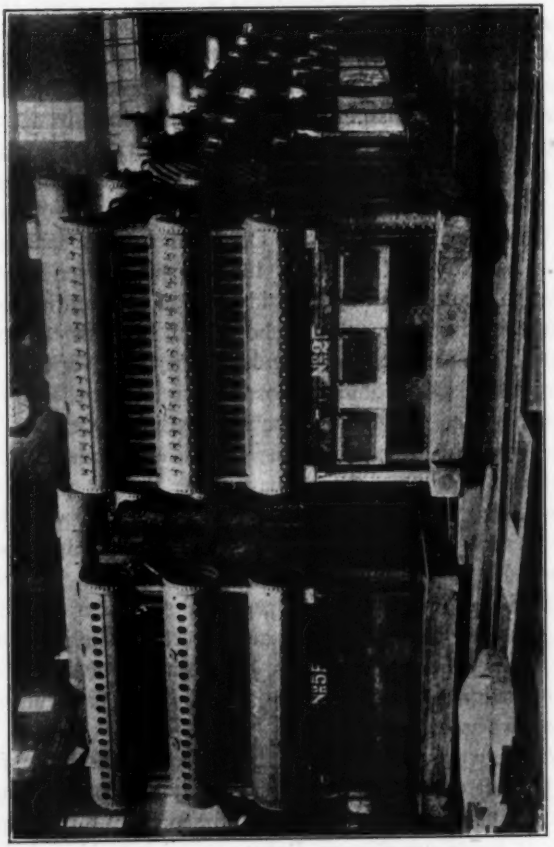


Fig. 2.—The Miyabara Boilers for "Sakura Maru."

As regards her fitness for cruiser work in war time, there are seven watertight bulkheads, and these, with the watertight bunker bulkheads, subdivide the vessel into eleven compartments. To afford protection against gun fire all the machinery is placed under the water line, and the watertight coal bunkers arranged along the sides of the machinery compartments. Rudder, steering gears, and communication apparatus are under the waterline. Prevention of fire is effected by dispensing with woodwork as much as possible, and by having all the main fire-service pipes below the waterline. Provision is made for the carrying of two 6-inch guns, six 12-pounders, two 20-inch searchlights, while wireless telegraphy, magazines, naval boats and other accessories for war service are arranged for.

There are four decks—boat deck, shelter deck, spar deck and main deck. The boat deck extends about 180 feet amidships, and forms a promenade for passengers. At the fore end of this deck there is a large house for the quarters of the navigating officers, with one special room for the first-class passengers. The roof of this deck house forms the flying-bridge. On the boat deck there are six 26-foot lifeboats, four of which have Axel Welin's patent quadrant davits, by means of which speed in working is obtained by the exertion of little force. They are also fitted with shifting chocks, permitting the boats to be chocked either fully inboard or along the extreme outer edge of the deck. Extra heavy davits are fitted for naval launches. There is also a searchlight platform aft on the boat deck.

At the forward end of the shelter deck there is a small deck house, which contains a companionway and lamp room, and serves as a shelter for two cargo winches. About amidships there is a large deck house, with an entrance hall to the dining saloon, and the companionway leading to the staterooms on the deck below. Ample natural light is provided in the way of the staircase by a large stained-glass skylight. On the central wall there is a large teak frame with bronze plaque bearing over 600 names of principal subscribers to the fleet. In general,

the fittings and decorations of all the public rooms are of neat and simple character. On this deck there are the dining saloon, which seats thirty-four persons at small tables, a reading room, the smoking room, and groups of staterooms, with convenient baths, lavatories, etc. Forward of the engine casing there is commodious accommodation for the chief engineer, and at the aft end an upper cold chamber with connection to a similar room on the deck below. A large steel deck house erected on the extreme aft end of the shelter deck is laid off at the fore end as a cargo winch house, and at the aft end as the hospital, and between these is placed the second-class smoking room.

The spar deck from stem to stern is covered. The petty officers and third-class passenger accommodation is at the fore end. The extreme aft end is devoted entirely to the second-class passenger accommodation, with a dining saloon to seat twenty-eight persons. A notable point in connection with the staterooms is that all the fold-up lavatories are fitted with the builders' patent "Hygene" vessel. The necessity for some other receptacle than the washbasin for the purpose of cleansing the mouth and teeth has been a long-felt want by all who have traveled on board ship, and the addition of this handy little vessel fitted on the side of the fold-up lavatory should be much appreciated.

For about 145 feet amidships the main deck is given up for the entire breadth of the ship to the turbine-room, boiler rooms, coal bunkers, workshop, dynamo and refrigerating-machine room. Forward of these there are sailors' and third-class stewards' quarters, also third-class pantry, the remaining portion of the fore 'tween decks is entirely used for third-class passengers. The aft 'tween decks is also fitted out for third-class passengers, in addition to the large space devoted to the mail rooms and storerooms.

A complete installation of refrigerating plant for the preservation of fresh provisions has been supplied by Messrs. J. Hall & Co., Dartford. The electric-generating plant consists of two sets of combined engines and dynamos of the compound type, either one of which is capable of generating and

supplying current for lamps equal to some 6,200 candlepower, three-cluster cargo lamps of 200 candlepower each, and for all signal lamps, motors, fans, etc. The current is transmitted by insulated cable of high conductivity, all wiring being done on the double-wire distribution-box system. The switchboard instruments are of the moving-coil type. Seventeen large overhead electric fans are distributed among the public rooms, and over forty small ball-socket portable fans among the first, second and third-class accommodation.

Each compartment has an outlet and inlet ventilator, and these are placed at opposite ends to produce a continuous current of air. In the third-class accommodation the foul air is exhausted through trunks led under the beams and by means of powerful electric fans.

As regards the machinery for working the ship, the steam windlass was supplied by Messrs. Harfield & Co.; steam warping capstan with horizontal engines by Messrs. Clarke, Chapman & Co.; cargo winches by the builders; the underwater-level steering gear, with telemotor and controlling rods in duplicate, by Messrs. Caldwell & Co.; engine-room telegraphs, steering and docking telegraphs, by Messrs. J. W. Ray & Co.; direction, tell-tale and revolution indicators on the flying bridge, by Messrs. Chadburn & Son; and Graham's marine-type loud-speaking telephone and speaking tubes.

The turbine propelling machinery is of the Parsons type, having the three-shaft arrangement now usually adopted for merchant steamers, with one high-pressure turbine coupled to the center line of shafting, and one low-pressure ahead and an astern turbine incorporated in the same casing, coupled to each wing shaft. Each line of shafting drives one solid Stone's manganese-bronze propeller. The turbines of the *Sakura Maru* are the first set designed and manufactured by the builders since they obtained the right for manufacturing the Parsons turbines in Japan, Korea and China.

The rotor wheels are cast steel, the spindles of forged steel of special quality, and the casings of cast iron. The blades are of hard-drawn brass, and are fixed in rotors and casings, in ac-

cordance with Parsons' usual design. The adjusting blocks, which are incorporated in the turbines, are so constructed that they can be readily adjusted while the turbines are running. The handles of all starting and maneuvering valves for ahead and astern turbines are accessible from the starting platform at the forward end of the engine room, and are operated entirely by hand, so that one engineer can have entire control of the whole machinery. With this arrangement the port and starboard turbines are capable of being worked ahead or astern independently of each other and of the high-pressure turbine, the latter rotating idly when maneuvering.

A governor working in conjunction with a throttle valve is fitted at the forward end of the turbine bearing. It is driven by worm gear from the rotor spindle. The governor on each shaft is arranged to act independently, and to close the throttle valve in the event of the shaft breaking, or the speed of the turbines exceeding the limit at which the governors are set, owing to the propellers racing in a sea-way. Chadburn's patent tachometers and tell-tales are fitted to the forward end of each turbine, and are so arranged that the engineer on watch can, from the starting platform, see not only the direction of rotation of each shaft, but also the rate of revolutions of each shaft.

The condensers—two in number—with steel-plate shells, are placed in the wings of the ship. Parsons' patent vacuum "Augmenter" is fitted to each condenser. Water is circulated through the condensers by two independent centrifugal pumps of the builders' make, and there are two sets of Messrs. Weir's twin air pumps of the latest type.

A surface feed-water heater has been fitted, with filter, and two pairs of Messrs. Weir's double-acting feed pumps. Each pair of these pumps is capable of supplying the boilers when the turbines are exerting their full powers. Two of Weir's direct-acting pumps are fitted for supplying oil under pressure to the turbine bearings, one of these being a stand-by.

The distilling plant includes two evaporators, together capable of producing from sea water 30 tons of fresh water

per 24 hours, and two distilling condensers having a combined output of 2,240 gallons of pure, fresh drinking water per day. The engineers' workshop is fitted with drilling machine, shaping machine, screw-cutting lathe, grinder, etc., driven by electric motor.

The boilers are arranged in two compartments, each of which has a separate funnel, and in each compartment there are fitted three Miyabara's patent water-tube boilers, the invention of Vice Admiral-Engineer Baron Jiro Miyabara, the late engineer-in-chief of the Imperial Navy. The boilers work under forced draft on the closed-stokehold system. Air is supplied by two fans, each driven by an independent double-acting steam engine. The gases exhaust into two large elliptical funnels. The funnels are double, the spaces between the inner and outer funnels being utilized for ventilating the boiler rooms and stokeholds. One of See's ash ejectors with donkey pump is fitted in each boiler room. For harbor duty two steam ash-hoisting engines are provided.

The full-speed trial of the *Sakura Maru* was run on September 26, 1908, over the measured 3,458 sea-mile Government course. Results of the six runs are as follows: First run down, 21.171 knots; second run up, 21.390 knots; third run down, 21.280 knots; fourth run up, 21.538 knots; fifth run down, 21.316 knots; sixth run up, 21.688 knots. The mean-of-means speed on the six runs was 21.393 knots, the guarantee speed on trial was 21 knots.

The vessel has been constructed under the supervision of Captain-Constructor Dr. Sakurai and Dr. Shin, members of the constructive committee of the Imperial Volunteer Fleet.—"Engineering."

OBITUARY.

LIEUTENANT DANIEL S. MAHONEY.

The death of Lieutenant D. S. Mahoney occurred on August 10th, at the Naval Hospital, Mare Island, Cal. By this death the Naval service loses a most valuable, efficient and zealous officer and the numerous persons of his acquaintance a true friend and agreeable companion. Lieutenant Mahoney was particularly regarded of great practical ability and solid common sense coupled with the highest regard for duty.

Lieutenant Mahoney was graduated from the Naval Academy in the class of '97, engineer division. He early exhibited engineering ability of a high order. His work in '97, then a Naval Cadet, in getting the machinery of the Cavite Navy Yard into working order after the same had been abandoned by the Spaniards, will be remembered by those stationed in Manila Bay at this time.

He served one tour of duty at the Bureau of Steam Engineering and another tour of duty as senior assistant to the Engineer Officer of the Navy Yard, Mare Island. Just previous to his death he was serving as Senior Engineer Officer of the U. S. S. *Washington.*

Lieutenant Mahoney was for twelve years a member of this Society, and during this time contributed several valuable papers for publication in this journal.

His career is an example of honest effort, strict devotion to duty and agreeable consideration, kindliness and respect to those with whom he was thrown in contact.

ENSIGN HUGH K. AIKEN.

The death of Ensign Hugh K. Aiken, on the U. S. S. *North Carolina,* on July 11th, will go on naval records as a sacrifice of life to duty. He died from the effects of an explosion of gases in a coal bunker on the *North Carolina* while engaged in investigating the condition of the bunker.

Ensign Aiken was born in Louisiana, and graduated from the Naval Academy in 1906. His last duty was as Assistant to the Engineer Officer of the U. S. S. *North Carolina.*

Ensign Aiken was an active member of this Society and was deeply interested in engineering; he was highly regarded as an officer by his companions and acquaintances in the service.

BOOKS RECEIVED.

THE MARINE STEAM TURBINE. By J. W. SOTHERN, M.I.E.S. Price 12s. 6d. net. Published by CROSBY LOCKWOOD & SON, 7 Stationers' Hall Court, Ludgate Hill, London.

In view of the prominence to which the steam turbine has been brought within the last few years, this work should be well received by progressive engineers the world over.

The present edition is a revision of the previous edition of same title.

In order to bring the present edition thoroughly up to date and to show the various new developments that have appeared during the last few years, the author has rewritten the greater portion of the previous edition and introduced a great deal of valuable and interesting new matter.

The aim of the author is to give a practical description of the Parsons marine turbine as at present constructed and fitted, and the work is thus mainly a description of Parsons practice. The work is divided into four sections with a handy and comprehensive index. Section 1 deals with the meaning of certain definitions which are connected with the theory and practice of the working of turbines. The general principles are also dealt with and numerous calculations for determining the power are given. Section 2, which is devoted to workshop practice, shows very fully the various systems which are at present in use in works where marine turbines are manufactured. The construction of the various parts of the machine are shown and explained. A large amount of very interesting data gathered from actual practice of vessels fitted with turbines is given in section 3. This, however, is largely confined to trial-trip results, which in various cases have not always been conclusive. In the last section the different types of torsion meters are shown and discussed, and formula for find-

ing the shaft H.P. from torsion reading is given. The combination of reciprocating engines and turbines are also dealt with in this chapter. The book is well got up and profusely illustrated throughout the text, there being over 180 diagrams, photographs and detail drawings. This work will be extremely valuable to all who have to deal with steam turbines.